DOCKETED	
Docket Number:	21-BSTD-04
Project Title:	2022 Energy Code Compliance Manuals and Forms
TN #:	243495
Document Title:	Final 2022 Nonresidential and Multifamily Compliance Manual Final
Description:	These are the final manuals adopted by the CEC. They contain information supplemental to the 2022 Energy Code regulations. The manuals are intended to help plans examiners, inspectors, owners, designers, builders, and energy consultants comply with and enforce California's 2022 Building Energy Efficiency Standards.
Filer:	Bach Tsan
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	6/9/2022 11:59:23 AM
Docketed Date:	6/9/2022

2022

NONRESIDENTIAL AND MULTIFAMILY COMPLIANCE MANUAL

FOR THE 2022 BUILDING ENERGY EFFICIENCY STANDARDS

TITLE 24, PART 6, AND ASSOCIATED ADMINISTRATIVE REGULATIONS IN PART 1

MAY 2022
CEC-400-2022-007-CMF

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ACKNOWLEDGMENTS

The Building Energy Efficiency Standards (Energy Code) were adopted and put into effect in 1978 and have been updated periodically in the intervening years. The Energy Code is a unique California asset that have placed the state on the forefront of energy efficiency, sustainability, energy independence, and climate change issues, and have provided a template for national standards within the United States as well as for other countries around the globe. They have benefitted from the conscientious involvement and enduring commitment to the public good of many persons and organizations along the way. The 2022 Energy Standards development and adoption process continues a long-standing practice of maintaining the standards with technical rigor, challenging but achievable design and construction practices, public engagement, and full consideration of the views of stakeholders.

The 2022 Energy Standards revision and the supporting documents were conceptualized, evaluated, and justified through the excellent work of California Energy Commission (CEC) staff and consultants working under contract to the CEC, supported by the utility-organized Codes and Standards Enhancement (CASE) Initiative, and shaped by the participation of over 150 stakeholders and the contribution of more than 1,300 formal public comments.

The authors would like to acknowledge the following staff and leaders:

Leadership — Commissioner Andrew McAllister and his advisor, Bill Pennington, for unwavering leadership throughout the standards development process; Payam Bozorgchami, P.E., senior engineer and overall project manager; Maziar Shirakh, P.E., senior engineer and building decarbonization lead; Haile Bucaneg, senior engineer and lead for mechanical measures; Javier Perez, senior specialist and lead for multifamily measures; Peter Strait, supervisor of the Standards Development Unit and interim acting manager of the Building Standards Office; Che Geiser, supervisor of the Standards Tools Unit; Chris Olvera, supervisor of the Outreach and Education Unit; and Will Vicent, manager of the Building Standards Office.

Legal Counsel — Under the leadership of the chief counsel, Linda Barrera, the following staff provided legal counsel: James Qaqundah, Matt Chalmers, Michael Murza, Josephine Crosby, Justin Delacruz, and Chester Hong.

Efficiency Division Staff - In the Building Standards Office: Thao Chau, P.E.; Cheng Moua, P.E.; Simon Lee, P.E.; Jeff Miller, P.E.; Ronald Balneg; Danuta Drozdowicz; Michael Shewmaker; Danny Tam; RJ Wichert; Haider Alhabibi; Muhammed Saeed; Amie Brousseau; Erik Jensen; Gagandeep Randhawa; and Allen Wong. In the Standards Compliance Office: Lorraine White; Charles Opferman; Ronnie Raxter; Samuel Cantrell; Javier Flores; Joe Loyer; Matthew Haro, P.E.; Armando Ramirez; Judy Roberson; and Daniel Wong, P.E. The following staff provided administrative support and editing: Christine Collopy; Corrine Fishman; Amber Beck; Tajanee Ford-Whelan; and Michi Mason.

Energy Commission Consultants — Key consultants include NORESCO, Bruce Wilcox, the California Statewide Codes and Standards Program – which is funded by California utility customers and administered by Pacific Gas and Electric Company, Southern California Edison Company, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District, under the auspices of the California Public Utilities Commission – and their consultants. The authors would also like to acknowledge the California Energy Alliance for the submission of their code change proposal relating to lighting in existing buildings. Key CEC and CASE consultants included NORESCO, Bruce Wilcox, Frontier Energy, McHugh Energy, and Energy Solutions. The CASE Initiative is supported by a consortium of California utility providers, which includes the Pacific Gas and Electric Company, Southern California Edison Company, San Diego Gas & Electric Company, the Sacramento Municipal Utility District, and the Los Angeles Department of Water and Power.

ABSTRACT

California's Building Energy Efficiency Standards were adopted in 1976 and have been updated periodically as directed by statute. In 1975, the Department of Housing and Community Development adopted rudimentary energy conservation standards under State Housing Law authority that were a precursor to the first generation of the standards. However, the Warren-Alquist Act[1] was passed one year earlier with explicit direction to the California Energy Commission (CEC), formally titled the State Energy Resources Conservation and Development Commission, to adopt and implement the standards. The CEC's statute created separate authority and specific direction regarding what the standards are to address, what criteria are to be met in developing the Standards, and what implementation tools, aids, and technical assistance are to be provided.

The standards contain energy and water efficiency requirements (and indoor air quality requirements) for newly constructed buildings, additions to existing buildings, and alterations to existing buildings. Public Resources Code sections 25402 subdivisions (a)-(b) and 25402.1 emphasize the importance of building design and construction flexibility by requiring the CEC to establish performance standards, in the form of an "energy budget" in terms of the energy consumption per square foot of floor space.

Public Resources Code section 25402.1 requires the CEC support the performance standards with compliance tools for builders and building designers. The Alternative Calculation Method (ACM) Approval Manual adopted by regulation as an appendix of the Standards establishes requirements for input, output, and calculational uniformity in the computer programs used to demonstrate compliance with the Standards. The CEC develops and makes publicly available free, public domain building modeling software to enable compliance based on modeling of building efficiency and performance. The ACM Approval Manual also includes provisions for private firms seeking to develop compliance software for approval by the CEC, which further encourages flexibility and innovation.

[1] Warren-Alquist Act 2022 Edition

Keywords:

California Energy Commission	mandatory	envelope insulation
California Building Code	prescriptive	HVAC
California Building Energy Efficiency Standards	performance	building commissioning
	time-dependent	process load
Title 24, Part 6	valuation	refrigeration
2022 Building Energy Efficiency Standards	TDV	data center
	ducts in conditioned spaces	exhaust
residential	high-performance attics	compressed air
nonresidential	high-performance walls	acceptance testing
newly constructed	high-efficacy lighting	data collection
additions and alterations to existing buildings	water heating	cool roof
	windows	on-site renewable
prescriptive	envelope insulation	source energy
controlled environment horticulture (CEH)	fan energy index (FEI)	mandatory

LINKS TO CHAPTERS

EXECUTIVE SUMMARY

The Compliance Manuals are intended to help plans examiners, inspectors, owners, designers, builders, and energy consultants comply with and enforce California's *2022 Building Energy Efficiency Standards*. These manuals contain information supplemental to the code regulations themselves and contain copies of compliance documents ("forms") used to demonstrate compliance. There are two compliance manuals: one for single-family homes and a second one for nonresidential buildings and multifamily buildings.

TABLE OF CONTENTS

1. Introduction

1.1 Organization and Content

This 2022 Nonresidential and Multifamily Compliance manual is designed to help building owners, architects, engineers, designers, energy consultants, builders, enforcement agencies, contractors and installers, and manufacturers comply with and enforce the California Building Energy Efficiency Standards (Energy Code) for nonresidential and multifamily buildings. The manual is a reference and instructional guide for anyone involved in the design and construction of energy-efficient nonresidential and multifamily buildings.

New for the 2022 Energy Code, the multifamily requirements have been grouped together regardless of number of stories. For this manual, all multifamily requirements are located in chapter 11. Where the requirements for multifamily common areas follow the nonresidential requirements, chapter 11 refers back to the appropriate nonresidential chapters.

Fourteen chapters make up the manual:

Chapter 1 Introduction of the Energy Code, application, and scope

Chapter 2 Compliance and enforcement process, including design and the preparation of compliance documentation through acceptance testing

Chapter 3 Building envelope

Chapter 4 Heating, ventilation, and air-conditioning (HVAC) systems and water heating systems

Chapter 5 Indoor lighting

Chapter 6 Outdoor lighting

Chapter 7 Sign lighting for indoor and outdoor applications

Chapter 8 Electrical power distribution

Chapter 9 Solar-ready requirements

Chapter 10 Covered processes requirements.

Chapter 11 Multifamily

Chapter 12 Performance approach

Chapter 13 Commissioning requirements

Chapter 14 Acceptance test requirements

Cross-references within the manual use the word "Section," while references to sections in the Energy Code are represented by "§."

1.2 Related Documents

This compliance manual supplements several other documents from the California Energy Commission (CEC):

A. *The 2022 Building Energy Efficiency Standards, Title 24, Part 6 (Energy Code).* This manual explains and supplements the Energy Code, the legal requirements for all covered buildings. This manual explains those requirements in simpler terms but does not replace or supersede them. Readers should have a copy of the Energy Code as a reference.

B. The 2022 Reference Appendices:

- Reference Joint Appendices contain information common to residential and nonresidential buildings.
- Reference Residential Appendices contain information for residential buildings only.
- Reference Nonresidential Appendices contain information for nonresidential buildings only.
- The 2022 Alternative Calculation Method (ACM) Approval and Nonresidential ACM Reference Manuals are specifications for compliance software.

Note: *Multifamily and hotel/motel occupancies – For the location and design data of these occupancies, opaque assembly properties are in the Reference Joint Appendices. Mechanical and lighting information is in the Reference Nonresidential Appendices. Residential water heating information is in the Reference Residential Appendices.*

Material from these documents is not always repeated in this manual. If you are using the electronic version of the manual, there may be hyperlinks to the reference document.

1.3 The Technical Chapters

Each of the 12 technical chapters (3 through 14) begins with an overview followed by each subsystem. For the building envelope, subsections include fenestration, insulation, infiltration, roofing products, and so forth. For HVAC, the subsections include heating equipment, cooling equipment, and ducts. Mandatory requirements and prescriptive requirements are described in each subsection or component. The prescriptive requirements establish the stringency of the Energy Code because they are the basis of the energy budget when the performance compliance method is used.

1.4 Why California Needs the Energy Code

Energy efficiency reduces energy costs for owners, increases reliability and availability of electricity for California, improves building occupant comfort, and reduces environmental impact.

1.4.1 Electricity Reliability and Demand

Buildings are a major contributor to electricity demand. The 2000 to 2001 California energy crisis and the East Coast blackout in the summer of 2003 illustrated the fragility of the electric distribution network. System overloads caused by excessive demand from buildings create unstable conditions. Blackouts disrupt business and cost the economy billions of dollars.

Since the California electricity crisis, the CEC has placed more emphasis on demand reduction.

1.4.2 Comfort

Comfort is an important benefit of energy-efficient buildings. Energy-efficient buildings include high-performance windows to reduce solar gains and heat loss, and properly designed HVAC systems, which improve air circulation. Poorly designed building envelopes result in buildings that are less comfortable. Oversized heating and cooling systems do not ensure comfort in older, poorly insulated, or leaky buildings.

1.4.3 Economics

Energy efficiency helps create a more profitable operation for building owners. More broadly, the less that California depends on depletable resources such as natural gas, coal, and oil, the stronger and more stable the economy will remain as energy costs increase. Investing in energy efficiency benefits everyone. It is more cost-effective to invest in saving energy than build new power plants.

1.4.4 Environment

The use of depletable energy has led to oil spills, acid rain, smog, and other forms of environmental pollution that threaten the natural beauty of the planet. California is not immune to these problems, but the Appliance Efficiency Regulations, the Energy Code, and utility programs that promote efficiency and conservation help maintain environmental quality. Other benefits include increased preservation of natural habitats, which protects animals, plants, and ecosystems.

1.4.5 Greenhouse Gas Emissions and Global Warming

Burning fossil fuel adds carbon dioxide (CO_2) to the atmosphere, a major contributor to global warming. Carbon dioxide and other greenhouse gases create an insulating layer that leads to global climate change. The CEC's research shows that most sectors of California economy face significant risk from climate change, including water resources (from reduced snowpack), agriculture, forests, and the natural habitats of indigenous plants and animals.

Energy efficiency is a far-reaching strategy to reducing greenhouse gases. The National Academy of Sciences has urged the country to follow California's lead on such efforts, saying that conservation and efficiency should be the chief elements in energy and global warming policy. Its first efficiency recommendation was to adopt nationwide energy efficiency building codes.

The Energy Code is expected to significantly reduce greenhouse gas and other air emissions.

1.4.6 Building Decarbonization

California has nearly 14 million homes and 7.5 million square feet of commercial buildings. These buildings produce a quarter of the state's greenhouse gas (GHG) emissions, making homes and businesses a major factor in climate change. Reducing these emissions, also referred to as building decarbonization, is a key part of California's climate strategy.[1] Of the many tools in the state's building decarbonization toolbox, the Building Energy Efficiency Standards stand out as a proven solution of significance.

In August 2021, the CEC adopted the 2022 Energy Code for newly constructed buildings and additions and alterations to existing buildings. This code blazes a trail for states and governments seeking to decarbonize the building sector aggressively, feasibly and cost-effectively. This update encourages efficient electric heat pumps, establishes electric-ready requirements for newly constructed homes, and strengthens ventilation standards. For the first time in the nation, this update also requires solar photovoltaic systems plus battery systems as the performance standards baseline (standard design) for select nonresidential building types. Over the next 30 years, this code is estimated to provide the state with $1.5 billion in environmental benefits; equivalent to taking nearly 2.2 million cars off the road for a year. The development of this code was a multiyear effort led by the CEC through a robust public process and with support from an expansive network of key market partners such as California's largest utilities, the building community, and environmental advocates.[2]

1.5 What's New for 2022

1.5.1 Envelope

Reduced the allowed area of site-built fenestration that is not rated by the National Fenestration Rating Council from 1,000 square feet (sq. ft) to 200 sq. ft (NA6).

1.5.2 Lighting

1. Changes to indoor and outdoor lighting power allowances to be based on light-emitting diode (LED) lighting technologies (§140.6 and §140.7) Revisions to

[1] AB3232, https://www.energy.ca.gov/media/5968

[2] 2022 code adoption script, https://www.energy.ca.gov/event/meeting/2021-08/energy-commission-business-meeting

lighting power density (LPD) values in Table 140.6-B, 140.6-C, 140.6-D, 140.7-A, and 140.7-B.

2. Revision and streamlining luminaire classification and wattage requirements.
3. New lighting power adjustment for small-aperture tunable white and dim-to-warm LED luminaires.
4. New power adjustment factors (PAFs) for daylighting devices including horizontal slats, light shelves, and clerestory fenestrations (§140.6[a]2L). New prescriptive requirements of daylighting devices including horizontal slats, light shelves, and clerestory fenestrations (§140.3[d]).
5. Clarification and streamlining of manual area controls requirements, multilevel lighting controls requirements, and automatic daylighting control requirements. Restrooms to comply with occupancy sensing control requirements. A new section for indoor lighting control interactions (§130.1).
6. Revision and streamlining of outdoor lighting control requirements (§130.2[c]).
7. Revision and streamlining of requirements for alterations, including the merging of three sections into a single "Altered Indoor Lighting Systems" section, the alignment of two reduced-power options on controls, and trigger threshold of projects more than 5,000 sq. ft. (§141.0[b]2I). Revised and consolidated Table 141.0-F.

1.5.3 Mechanical

1. New mandatory requirements for demand response HVAC controls (§110.12[a] and §110.12[b]).
2. New mandatory requirements for ventilation and indoor air quality (§120.1).
3. Revision of the mandatory requirements for demand control ventilation (§120.1[d]).
4. Healthcare buildings overseen by the California Department of Health Care Access and Information (HCAI) (formerly the Office of Statewide Health Planning and Development (OSHPD)) shall comply with the Energy Code. However, there are exceptions for healthcare facilities to avoid conflicting requirements.
5. Revision of the requirements for occupancy-sensing zone controls (§120.2[e]3).
6. Revision of the mandatory requirements for economizer fault detection and diagnostics (§120.2[i] and §140.9[a]1A).
7. New mandatory requirements for adiabatic condensers for heat rejection for refrigeration systems (§120.6).
8. Revision of the prescriptive requirements for fan power limitation (§140.4[c]).
9. New prescriptive requirements for space-conditioning zone controls (§140.4[d]).
10. New prescriptive requirements for water economizers (§140.4[e]3).
11. New prescriptive requirements for cooling tower efficiency (§140.4[h]5).
12. New prescriptive requirements for exhaust system transfer air (§140.4[o]).

13. New prescriptive requirements calling for heat pump water heaters for smaller school buildings, higher efficiency for high-capacity gas water heating; hotel/motels are required to meet reorganized multifamily water heating requirements. (§140.5)
14. New requirements for Dedicated Outside Air Systems (§140.4[p]).
15. New requirements for Exhaust Air Heat Recovery(§140.4[q]).

1.5.4 Electrical

1. Healthcare facilities overseen by the (OSHPD) have to comply with the applicable requirements of Section 130.5 for electrical power distribution systems. There are exceptions for healthcare facilities to avoid potentially conflicting requirements for healthcare facilities.

1.5.5 Covered Processes

1. New mandatory requirements for controlled environmental horticulture systems (§120.6[h]).
2. New mandatory requirements for steam traps (§120.6[i]).
3. New mandatory requirements for compressed air systems (§120.6[e]).
4. New mandatory requirements for computer rooms, including uninterruptible power supplies, and revisions to existing prescriptive requirements for economizers for computer rooms (§120.6[j], §140.9[a], and §141.1[b]).
5. New mandatory requirements for transcritical CO_2 refrigeration systems (§120.6[b]).

1.5.7 Multifamily

1. The new chapter 11 of this manual consolidates multifamily compliance into one chapter.
2. The 2022 Energy Code grouped all multifamily building requirements together, regardless of number of stories, and relocated all relevant multifamily code to sections § 160.0 through 180.2.
3. Revisions to language and content to §160.0

1.6 Mandatory Requirements and Compliance Approaches

1.6.1 Mandatory Requirements

With either the prescriptive or performance compliance paths, there are mandatory requirements that always must be met. Mandatory requirements include infiltration control, lighting systems, minimum insulation levels, and equipment efficiency. The minimum mandatory levels are sometimes superseded by more stringent prescriptive or performance requirements.

1.6.2 Prescriptive Approach

The prescriptive approach (composed of requirements described in Chapters 3, 4, 5, 6, 7, 10, and 11) requires each component of the proposed building to meet a prescribed minimum efficiency. The approach offers little flexibility but is easy to use. If the design fails to meet even one requirement, then the system does not comply with the prescriptive approach. In this case, the performance approach provides more flexibility to the building designer for choosing alternative energy efficiency features.

A. **Building Envelope**. The prescriptive envelope requirements are the required thermal performance levels for each building component (walls, roofs, and floors). These requirements are described in Chapter 3. The only flexibility is if portions of an envelope component do not meet a requirement, a weighted average of the component can be used to demonstrate compliance. The stringency of the envelope requirements varies according to climate zone and occupancy type.

B. **Mechanical**. The prescriptive mechanical requirements are described in Chapter 4. The prescriptive approach specifies equipment, features, and design procedures but does not mandate the installation of a particular HVAC system.

C. **Indoor Lighting**. The prescriptive lighting power requirements are determined by one of three methods: the complete building method, the area category method, or the tailored method. These approaches are described in Chapter 5. The allowed lighting varies according to the requirements of the building occupancy or task requirements.

D. **Outdoor Lighting**. Outdoor lighting standards are described in Chapter 6, setting power limits for various applications such as parking lots, pedestrian areas, sales canopies, building entrances, building façades, and signs. The Energy Code also set minimum requirements for cutoff luminaires and controls. Detailed information on the outdoor lighting power allowance calculations is in Section 6.4.

1.6.3 Performance Approach

The performance approach (Chapter 12) allows greater flexibility than the prescriptive approach. It is based on an energy simulation model of the building.

The performance approach requires an approved computer compliance program that models a proposed building, determines the allowed energy budget, calculates the energy use of the building, and determines when it complies. Design options such as window orientation, shading, thermal mass, zonal control, and building configuration are all considered in the performance approach. In addition to flexibility, it helps find the most cost-effective solution for compliance.

The performance approach may be used for:

- Envelope or mechanical compliance alone.

- Envelope and mechanical compliance.
- Envelope and indoor lighting compliance.
- Envelope, mechanical, and indoor lighting compliance.

Indoor lighting compliance must be combined with envelope compliance. The performance approach does not apply to outdoor lighting, sign lighting, exempt process load, some covered process loads (for example, refrigerated warehouses), or solar-ready applications.

Time-dependent valuation (TDV) energy and Hourly Source Energy (HSE) are the "currency" for the performance approach. TDV energy considers the utility costs associated with the type of energy (electricity, gas, or propane) and the time when it is saved or used. Energy saved when California is likely to have a statewide system peak is worth more than when supply exceeds demand. Appendix JA3 of the Reference Appendices has more information on TDV energy. Like TDV, HSE considers the type of energy (electricity, gas, or propane), but is based on the amount of long-term depletable energy resources used to meet the energy demand of the building in each hour. HSE values are very similar to the long-term hourly utility greenhouse gas emissions and a strong metric for encouraging building decarbonization.

See Chapter 12 if the performance approach will be used for additions and alterations.

1.6.3.1 Compliance Options

The CEC has a formal process for certification of compliance options for new products, materials, designs, or procedures that can improve building efficiency. Section 10-109 allows the introduction of new calculation methods and requirements that cannot be properly accounted for in the current approved compliance approaches. The compliance options process allows the CEC to review and gather public input about the merits of new compliance techniques, products, materials, designs, or procedures to demonstrate compliance for newly constructed buildings and additions and alterations to existing buildings.

Approved compliance options encourage market innovation and allow the CEC to respond to changes in building design, construction, installation, and enforcement.

1.7 Scope and Application

The Energy Code applies to nonresidential and residential buildings. This manual addresses the requirements for nonresidential buildings, including hotels, motels, and multifamily buildings. The Residential Manual discusses the requirements for single-family residential buildings.

1.7.1 Building Types Covered

The nonresidential standards apply to all California Building Code (CBC) occupancies of Group A, B, E, F, H, I, M, S, and U. If buildings are directly or indirectly conditioned, they must meet all mechanical, envelope, indoor, and outdoor lighting requirements of the standards. Buildings that are not directly or indirectly conditioned must meet only the indoor and outdoor lighting requirements.

The Energy Code does not apply to CBC Group L. The standards also do not apply to buildings that fall outside the CBC's jurisdiction, such as mobile structures. If outdoor lighting is associated with a Group L occupancy, it is exempt. If the outdoor lighting is part of any other occupancy groups listed, it must comply.

1.7.2 Historical Buildings

Exception 1 to §100.0(a) states that qualified historical buildings, as regulated by the California Historical Building Code Title 24, Part 8, or California Building Code, Title 24, Part 2, Volume I, Chapter 34, Division II, are not covered by the Energy Code. Section 140.6(a)3Q and Exception 13 to §140.7(a) clarify that indoor and outdoor lighting systems in qualified historical buildings are exempt from the lighting power allowances only if they consist solely of historical lighting components or replicas of historical lighting components. If lighting systems in qualified historical buildings contain some historical lighting components or replicas of historical components, combined with other lighting components, only those historical or historical replica components are exempt.

The California Historical Building Code (CHBC) Section 102.1.1 specifies that all nonhistorical additions must comply with the regular code , including the Energy Code. CHBC Section 901.5 specifies that when new nonhistorical mechanical, plumbing, or electrical (including lighting) equipment or appliances or a combination is is installed historic buildings, they *must* comply with the Energy Code and Appliance Efficiency Regulations unless historical significance or characteristic features are threatened.

The California State Historical Building Safety Board has final authority for interpreting the requirements of the CHBC and determining to what extent the requirements of the Energy Code apply to new and replacement equipment and other alterations to qualified historic buildings. In enacting the CHBC legislation, the Legislature wants to encourage energy conservation in alterations to historic buildings (Health and Safety Code Section 18951).

Additional information about the CHBC can be found at http://www.dgs.ca.gov/dsa/AboutUs/shbsb.aspx.

Contact the State Historical Building Safety Board at (916) 445-7627.

1.7.3 Residential Buildings

The 2022 Energy Code has grouped all multifamily building requirements together, regardless of number of stories, and relocated all relevant multifamily code language to Sections 160.0 through 180.2 of the Energy Code. Requirements specific to single-family buildings continue to be found in Sections 150.0 through 150.2. Table 1-1 describes how single-family and multifamily buildings are classified.

Table 1-1: Nonresidential vs. Residential Energy Standards

Nonresidential Standards	Multifamily Standards	Single-Family Standards
These standards cover all nonresidential occupancies (Group A, B, E, F, H, I, M, S, or U), and all hotel and motel occupancies.	These standards cover residential occupancy groups R-2, R-3, and R-4 as described below.	These standards cover residential occupancies as described below:
Offices Retail and wholesale stores Grocery stores Restaurants Assembly and conference areas Industrial work buildings Commercial or industrial storage Schools and churches Theaters Hospitals Hotels and motels	A building of occupancy group R-2, other than a hotel/motel building or timeshare property. A building of occupancy group R-3 that is a nontransient congregate residence, other than boarding houses of more than 6 guests and alcohol or drug abuse recovery homes of more than 6 guests. A building of Occupancy Group R-4.	A building of occupancy group R-3 with two or less dwelling units. A building of occupancy group R-3, other than a multifamily building or hotel/motel building. A townhouse. A building of occupancy group R-3.1. A building of occupancy group U when located on a residential site.

Notes: Occupancy groups are defined in Chapter 3 of the California Building Code (Title 24, Part 2, Volume I). Any buildings of occupancy group R that are not identified under the single-family or multifamily columns are considered hotel/motel buildings. For more on hotel/motel buildings and their occupancy groups, see Section 1.7.8 of this manual.

Source: California Energy Commission

1.7.4 Scope of Standard Requirements

The Energy Code applies to any construction that requires a building permit, whether for newly constructed buildings, outdoor lighting systems, signs, or additions or alterations to them. The primary enforcement mechanism is the building permitting process. Until the enforcement agency is satisfied that the building, outdoor lighting, or sign complies with all applicable code requirements, including the Energy Code, it has the authority to not approve the building or occupancy permit.

The Energy Code applies only to the construction subject to the building permit application. An existing space that is "conditioned" for the first time is an addition, and all the existing components, whether altered or not, must comply with the Energy Code. (See §100.1 addition or newly conditioned space.)

Other than for lighting, the Energy Code requirements apply only to buildings that are directly or indirectly conditioned.

1.7.5 Speculative Buildings

1.7.5.1 Known Occupancy

Speculative buildings of known occupancy are commonly built by developers. For example, if a big box retail center or an office building was built on speculation, the owner would know the ultimate occupancy of the space but might not know the specific tenant. For this building, the owner has two compliance choices:

1. Declare the building to be unconditioned space, forcing tenants to be responsible for envelope, interior lighting, possibly some exterior lighting, and mechanical compliance. This option may be very costly as most envelope and mechanical requirements are far more expensive when they are installed in the building after the shell is built.
2. Include envelope compliance as well as mechanical or lighting compliance or both when those systems are to be installed prior to leasing.

A potential pitfall with delaying envelope compliance is that tenants may have a difficult time showing compliance. An Energy Code update between the time of shell construction and energy compliance for a tenant improvement could make compliance more difficult. Constructing a big-box-style building without skylights, where skylights are required under the prescriptive approach, will also create a compliance challenge (and possibly impose large retrofit costs). In most cases, delaying the envelope increases construction costs. If a building is likely to be conditioned, some enforcement agencies require envelope compliance when the shell is constructed.

Section 1.7.12 has information about energy compliance for tenant improvements in existing buildings.

1.7.5.2 Unknown Occupancy

Speculative buildings may be built, and the ultimate occupancy is determined only when the building is leased. The structure could be an office, a restaurant, or retail space. The Energy Code building envelope requirements treat these occupancies similarly. The major differences are the lighting and ventilation requirements. If a tenant is not identified during the permitting time, the "all other areas" lighting power densities in Table 140.6-C are used.

Deferring compliance by calling the building unconditioned will cause problems when the first tenant installs mechanical space-conditioning equipment.

1.7.6 Mixed- and Multiple-Use Buildings

1.7.6.1 Mixed Residential and Nonresidential Occupancies

When a building includes both residential and nonresidential occupancies, the requirements depend on the percentages of conditioned floor area for each occupancy type:

A. **Minor Occupancy** (Exception 1 to §100.0[f]). When a residential occupancy is in the same building as a nonresidential occupancy, and if one of the occupancies is less than 20 percent of the total conditioned floor area, the smaller occupancy is considered a "minor" occupancy. Under this scenario, the applicant may choose to treat the entire building as if it is the major occupancy for envelope, HVAC, and water-heating compliance. Lighting requirements in §140.6 through §140.8 or §150.0(k) must be met for each occupancy separately. The mandatory requirements that apply to the minor occupancy, if different from the major occupancy, would still apply.

B. **Mixed Occupancy.** When a residential occupancy is mixed with a nonresidential occupancy, and if neither occupancy is less than 20 percent of the total conditioned floor area, two compliance submittals are prepared, each using the calculations and documents of the respective standards. Separate compliance for each occupancy is an option when one of the occupancies is a minor occupancy.

1.7.6.2 Multiple Nonresidential Occupancies

When a building consists of multiple nonresidential occupancies, they are considered separate occupancies. Most occupancies have the same envelope requirements. Lighting and mechanical requirements vary among the various usage categories and are treated according to each appropriate occupancy type.

Example 1-1

Question

A 250,000 sq. ft high-rise office building includes a small 900 sq. ft apartment on the first floor that visiting executives use. Is the apartment required to meet the residential requirements of the Energy Code?

Answer

No. The apartment occupies less than 20 percent of the total conditioned floor area, so it is a minor occupancy and may be treated as part of the office occupancy.

1.7.7 Multifamily Buildings

Multifamily buildings are covered by chapter 11 of this manual.

1.7.8 Hotels and Motels

This section discusses the similarities and differences among the requirements for a hotel/motel and other nonresidential buildings.

Hotels or motels are unique in that the design incorporates a wide variety of occupancies and functions into one structure. The occupancies range from nonresidential occupancies to hotel/motel guest rooms. Design functions that affect guests range from the arrival experience created through the architectural features of the main lobby to the thermal comfort of the guest rooms. Other functions that designs must address include restaurants, kitchens, laundry, storage, assembly, outdoor lighting, and sign lighting. These structures can range from simple guest rooms with a small office to a structure encompassing a small city (§100.1 "HOTEL/MOTEL").

The 2022 Energy Code expanded on the definition of "Hotel/Motel" to include the following:

- A building of Occupancy Group R-1,
- Vacation timeshare properties and hotel or motel buildings of Occupancy Group R-2, and
- The following types of Occupancy Group R-3:
    - Congregate residences for transient use,
    - Boarding houses of more than 6 guests, and
    - Alcohol or drug abuse recovery homes of more than 6 guests.

Like other occupancies, compliance is submitted for the features covered in the permit application only. The nonresidential areas must meet the envelope, mechanical, indoor lighting, outdoor lighting, and sign lighting portions of the nonresidential Energy Code. The guest room portions of hotels/motels must meet the envelope, mechanical, and lighting provisions applicable only to hotel/motel guest rooms. Each portion of the building individually complies with the provisions applicable to that occupancy.

Since hotel/motels are treated as a mixture of occupancies covered by the Energy Code, the concepts at the beginning of each chapter apply to hotels/motels as they would any other nonresidential occupancy.

1.7.8.1 Mandatory Requirements

The mandatory requirements for envelope, mechanical, indoor lighting, outdoor lighting, and sign lighting apply to hotels/motels. The following describes special requirements or exceptions:

- Hotel/motel guest rooms must meet the applicable residential lighting standards.
- Outdoor lighting must meet the applicable outdoor lighting standards.
- Indoor and outdoor signs (other than exit signs) must comply with nonresidential Energy Code. Exit signs must comply with the Appliance Efficiency Regulations.
- Hotel and motel guest room thermostats shall have numeric temperature settings (Section 120.2(c)1A).
- Readily accessible area switching controls are not required in public areas provided switches that control the lights in public areas are accessible to authorized personnel.

- Automatic lighting shutoff controls are not required for hotel/motel guest rooms.

1.7.8.2 Prescriptive Compliance

The prescriptive requirements for envelope, mechanical, and lighting apply to hotel/motels. The following prescriptive requirements are specific to hotel/motels:

- Hotel/motel guest rooms must meet the prescriptive envelope criteria for high-rise residential buildings rather than the prescriptive criteria for nonresidential buildings.
- Hotel and motel guest rooms are not required to have economizer controls.
- Guest rooms in hotel/motels are exempt from the lighting power density requirements. However, lighting must meet the residential requirements of §150.0(k).
- Each occupancy (other than guest rooms) in the hotel/motel must comply with the Nonresidential Lighting Standards.
- For compliance with water heating requirements, use the residential compliance.

1.7.8.3 Performance Compliance

The rules for performance compliance are based on the prescriptive and mandatory requirements for hotel/motels. However, the performance compliance approach can provide more flexibility than prescriptive compliance because of the ability to trade improvements in energy efficiency in one building component for reductions in efficiency in others.

To use the performance approach, the proposed building is modeled in compliance software. Proposed building details such as, building areas and occupancies for each area (including hotel/motel, nonresidential, and other occupancies if present) and envelope, mechanical and lighting specifications are input into the software. Based on the proposed design, the compliance software calculates standard design energy budgets. To comply, the proposed design energy use must be less than or equal to the standard design energy budget’s. Details on the performance approach are covered in chapter 12 of this manual.

1.7.9 Live-Work Spaces

Live-work buildings combine residential and nonresidential uses within individual units. In general, the residential requirements (depending on the number of habitable stories) apply since these buildings operate and are conditioned 24 hours per day. Lighting in designated workspaces is required to show compliance with the nonresidential lighting standards (§140.6).

1.7.10 Unconditioned Space

An unconditioned space is neither directly nor indirectly conditioned. Both the requirements for lighting and minimum skylight area apply to unconditioned space. Some typical examples of spaces that may be unconditioned:

- Enclosed parking structures
- Automotive workshops
- Enclosed entry courts or walkways
- Enclosed outdoor dining areas
- Greenhouses
- Loading docks
- Warehouses
- Mechanical/electrical equipment rooms

These spaces are not always unconditioned. The specifics of each case must be determined.

1.7.11 Newly Conditioned Space

When previously unconditioned space becomes conditioned, the space is an addition, and all the components of the building must comply as if it were a newly constructed building with few exceptions, as described in Section 141.0(a) of the Energy Code.

This situation has potentially significant construction and cost implications. If an unconditioned warehouse is upgraded with a heating system, thus becoming conditioned space, the building envelope must comply with the current envelope requirements, and the lighting system must conform with the current lighting requirements, including mandatory wiring and switching. If the envelope has large windows, some may have to be eliminated or replaced with more efficient windows. If the lighting system is inefficient, new and more efficient fixtures might have to be installed.

For example, the owner of an office building obtains a permit for the structure and envelope but wants the tenants to handle conditioning and lighting improvements. If that owner claims unconditioned status for that building, the owner does not have to comply with the envelope requirements of the standards. The owner does have to demonstrate compliance with the lighting requirements. If a tenant is not identified for a multitenant space during the permitting time, the “all other areas” lighting power density allowances from Energy Code Table 140.6-C shall be used. When the tenant applies for a permit to install the HVAC equipment, the envelope and any existing lighting to remain must fully comply with the requirements for the occupancy designated.

This is the only circumstance when systems, other than those subject to the current permit application, fall under the Energy Code. If the building was initially designed in a way that makes compliance difficult, the building envelope may require expensive alterations to bring it into compliance.

Many enforcement agencies require the owner to sign an affidavit at the time of the initial building permit for the shell, acknowledging the potential difficulties of future envelope or lighting compliance.

To minimize difficulties, the recommended practice is to demonstrate energy compliance when the envelope is built and comply with the lighting systems during installation.

1.7.12 New Construction in Existing Buildings

Tenant improvements, including alterations and repairs, are new construction in an existing building. For example, the base building was constructed, but the individual tenant spaces were not completed. Tenant improvements can include work on the envelope, mechanical, or lighting systems. The system or systems being installed are new construction and must comply with some or all of the current standards depending on the extent of the changes. (See following sections.)

The only time systems other than those subject to the current permit application are involved is when the tenant improvement results in the conditioning of previously unconditioned space.

1.7.13 Alterations to Existing Conditioned Spaces

§141.0(b)

An alteration is any change to the water heating system of a building, space-conditioning system, indoor lighting system, outdoor lighting system, sign lighting, or envelope that is not an addition. Alterations or renovations to existing conditioned spaces have separate rules for energy compliance.

In summary, the alteration rules are the following:

1. The Energy Code applies only to those portions or components of the systems being altered (altered component). Untouched portions or components need not comply with the standards.
2. Alterations must comply with the mandatory requirements for the altered components.
3. New systems in the alteration must comply with the current standards.
4. An existing unconditioned building, where evaporative cooling is added to the existing unaltered envelope and lighting, does not need to comply with current standards.
5. Mechanical system alterations are governed primarily by the mandatory requirements.

Beyond meeting all applicable mandatory requirements, alterations must also comply with applicable prescriptive requirements discussed in technical chapters or use the performance approach. Within the performance approach, the option to show changes to the existing building (existing and alteration) is explained in Chapter 12. Performance credit is given only for systems that are changing under the current permitted scope of work.

Example 1-2

Question

An owner wants to add less than 50 sq. ft of new glazing in an existing nonresidential building in Climate Zone 3. What are the applicable requirements for the new glazing?

Answer

Exception 2 to §141.0(b)2Aii exempts up to 50 sq. ft of added windows from the relative solar heat gain coefficient (RSHGC) and visual transmittance (VT) requirements in Table 140.3-B, 140.3-C, and 140.3-D. The new glazing must meet only the Climate Zone 3 U-factor requirement in Table 141.0-A.

Example 1-3

Question

A building owner wants to change existing lighting fixtures with new ones. Does the Energy Code restrict the change in any way?

Answer

If more than 10 percent of the fixtures are replaced in the permitted space (excluding enclosed spaces where no new lighting fixtures are proposed), or the connected load is increased, the standards will treat this as a new lighting system that must comply with §141.0(b)2I. Any applicable mandatory requirement affected by the alteration applies. The mandatory switching requirements would apply to the improved system if the circuiting were altered. Appliance efficiency regulations requirements for ballasts would also apply.

Example 1-4

Question

A building owner wants to rearrange some interior partitions and reposition the light fixtures in the affected rooms. Does the Energy Code apply to the work?

Answer

Each of the newly arranged rooms must have light switches. Since there is no change in the connected lighting load or the exterior envelope, only the mandatory light switching requirements in §130.1 would apply.

Example 1-5

Question

A building owner wants to rearrange some duct work and add some additional fan coils to an existing HVAC system to improve comfort. Does the Energy Code apply to the work?

Answer

There would be no change in the load on the system nor any increase in the overall capacity, so the Energy Code would not apply to the central system. Only the duct construction requirements apply to altered ducting.

Example 1-6

Question

A building owner wants to replace an existing chiller. No other changes will be made to the HVAC system. Does the Energy Code restrict the change in any way?

Answer

The mandatory efficiency requirements would govern the efficiency of the new chiller. The other parts of the system are unchanged and unaffected by the Energy Code.

Example 1-7

Question

A building has a high ceiling space, and the owner wants to build a new mezzanine space. There will be no changes to the building envelope or the central HVAC system. There will be new lighting installed. How does the Energy Code apply?

Answer

Since a mezzanine does not add volume, it is an alteration, not an addition. The existing systems are not affected unless they are altered. The new lighting must comply with all requirements of the Energy Code. The envelope is unchanged, so there are no requirements for it. The mechanical system duct work is simply extended without increase in system capacity, so only the duct construction and insulation requirements apply.

1.7.14 Additions

§141.0(a)

An addition is any change to a building that increases floor area and conditioned volume. Additions involve the:

- Construction of new conditioned space and conditioned volume.
- Installation of space conditioning in a previously unconditioned space.
- Addition of unconditioned space.

Mandatory requirements and either prescriptive or performance requirements apply. For conditioned space, the heating, lighting, envelope, and water-heating systems of additions are treated the same as those for new buildings.

If the existing mechanical system(s) is simply extended into the addition, Exception 1 to §141.0(a) applies. Unconditioned additions shall comply only with indoor, outdoor lighting, and sign lighting requirements of the standards. Refer above to Section 1.7.11 for further discussion of previously unconditioned space.

There are three options for the energy compliance of additions under the Energy Code:

Option 1 – Addition Alone

Treat the addition as a stand-alone building with walls to conditioned space treated as adiabatic (§141.0[a]1 and §141.0[a]2Bi). This option can use either the prescriptive or performance approach. *Adiabatic* means the common walls are assumed to have no heat transfer between the addition and the adjacent conditioned space .

Option 2 – Existing-Plus-Addition-Plus-Alteration

Using performance compliance, model the combination of the existing building, any alterations to the existing building, plus the addition (§141.0[a]2Bii). In this scenario, the proposed energy use is calculated based on existing building features that remain unaltered, the alterations to the existing building, and the proposed addition. The standard design (allowed) energy budget is calculated by approved software based on:

1. The existing building features that remain unaltered.
2. All altered features modeled to meet requirements of §141.0(b).
3. The addition modeled to meet requirements of §141.0(a)1.

If the proposed building energy use is less than or equal to the standard design energy budget, then the building complies. The standard design for any alterations to the existing lighting or mechanical systems is based on the requirements for altered systems in §141.0(b).

This compliance option will generally ease the energy requirements of the addition only if there are energy improvements to the existing building. It may allow the designer to make up for an inefficiency of the addition depending on the nature and scope of improvements to the existing building.

Option 3 – Whole Building as All Newly Constructed

The existing structure combined with the addition can be shown to comply as a whole building meeting all requirements of the Energy Code for newly constructed buildings for envelope, lighting, and mechanical. This is the most stringent and is practical only if the existing building will be improved to the overall level of the current Energy Code.

Example 1-8

Question

A restaurant adds a conditioned greenhouse-style dining area with very large areas of glazing. How can it comply with the Energy Code?

Answer

Because of the large glass area, it will not comply on its own. By making substantial energy improvements to the existing building (envelope, lighting, and mechanical features), or by upgrading the existing building so that the entire building meets the requirements for newly constructed buildings, it is possible for the combined building to comply. The performance approach would be used to model the entire building as an existing-plus-addition.

To accumulate enough energy credit that can be used to offset (trade off against) the large glazing area in the addition, several design strategies are available, including one or a combination of the following:

1) Envelope improvements to the existing building that exceed the performance of the requirements in §141.0(b)1 and §141.0(b)2A and B

2) New indoor lighting in the existing building that has a lower installed lighting power density (LPD) than the allowed LPD in §140.6

3) Existing building mechanical system improvements that exceed the requirements of §141.0(b)2C, D, and E.

1.7.15 Change of Occupancy

A change of occupancy alone without any tenant improvements or other changes does not require any action under the Energy Code. If alterations are made to the building, then the rules for alterations or additions for the new occupancy apply. (See Sections 1.7.13 and 1.7.14.)

If no changes are proposed for the building, consider the ventilation requirements of the new occupancy. For example, if a residence is converted to a hair salon, with new sources of indoor pollution, existing residential ventilation rates would likely be inadequate. The Energy Code requires no changes. If changes are made, then those alterations are required to comply.

1.7.16 Repairs

A repair is reconstructing or renewing any part of an existing building for maintaining it. Repairs shall not increase the preexisting energy consumption of the required component, system, or equipment. The Energy Code does not apply to repairs.

Example 1-9

Question

If a space were 1,000 sq. ft, how large would the heating system have to be to make the space directly conditioned?

Answer

The heating system would have to be larger than 10 British thermal units (Btu)/hour (hr)-sq. ft =(hr-ft²) x 1,000 sq. ftft² = 10,000 Btu/hr output to meet the definition of directly conditioned space.

Example 1-10

Question

A water treatment plant has a heating system installed to prevent pipes from freezing. The heating system exceeds 10 Btu/(hr-sq. ftft²) and operates to keep the space temperature from falling below 50 degrees Fahrenheit (°F). Is this plant directly conditioned?

Answer

Not if the heating system is sized to meet the building load at 50°F and is thermostatically controlled to prevent operating temperatures above 50°F. The definition of directly conditioned space excludes process spaces that have space conditioning designed and controlled to be incapable of operating at temperatures above 55°F at design conditions. Under these conditions, the space is not directly conditioned.

Example 111

Question

A process load in a manufacturing plant is generating heat inside the building shell. The manufacturing plant will install space cooling to keep the temperature from exceeding 90°F. If the thermostat will not allow cooling below 90°F (that is, the temperature is kept at 90°F all the time), is this facility directly conditioned if the mechanical cooling exceeds 5 Btuh/hr-sq. ft?

Answer

No, this facility is not a directly conditioned space. The definition of directly conditioned space excludes spaces where the space-conditioning system is designed and controlled to be incapable of operating at temperatures below 90°F at design conditions.

Example 1-12

Question

A natural gas kiln in a factory is in the building shell, and its capacity exceeds 10 Btu/(hr-sq. ft). Is the space within the shell considered directly conditioned space if there is no HVAC system installed in the building?

Answer

No. Since the heat from the kiln is an exempt process load and not part of heat that is transferred across the building envelope components, and there is no HVAC system installed, the space is not considered a directly conditioned space, and the shell does not have to meet the Energy Code envelope requirements. However, the space must still meet the lighting requirements of the Energy Code.

Example 1-13

Question

If in the example above mechanical cooling with the capacity that exceeds 5 Btu/hr-sq. ft is added to the building to keep the temperature from exceeding 85°F, is the space considered directly conditioned, and must the envelope meet the Energy Code requirements?

Answer

No, the definition of directly conditioned space excludes conditioning for process loads.

Example 1-14

Question

If a computer room is cooled with the capacity that exceeds 5 Btu/hr-sq. ft and is controlled to a temperature of 75°F, does the space have to meet the envelope requirements of the Energy Code?

Answer

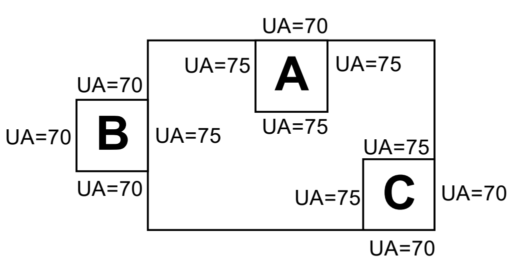
No. Computer rooms are a covered process. There are no envelope requirements in either §120.6 or §140.9.

Example 115

Question

The accompanying sketch shows a building with three unconditioned spaces. (None has a direct source of mechanical heating or cooling.) The air transfer rate from the adjacent conditioned spaces is less than three air changes per hour. The area weighted heat transfer coefficients of the walls (UA) are shown on the sketch. The roof/ceiling area weighted heat transfer coefficients (UA) for each of the three unconditioned spaces is 90 Btu/hr -°F.

Are any of these spaces indirectly conditioned?



Answer

Because the air change rate is low, each space is evaluated on the basis of heat transfer coefficients through the walls and roof. It is further assumed that the floors are adiabatic. The heat transfer will be proportional to the area weighted heat transfer coefficients of the walls and roof/ceilings.

SPACE A: The area weighted heat transfer coefficient to directly conditioned space is 3 x (75 Btu/hr-°F) = 225 Btu/hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is 70 Btu/hr-°F + 90 Btu/hr-°F = 160 Btu/hr-°F. Since the heat transfer coefficient from Space A to the conditioned space is greater than heat transfer coefficient from Space A to outside, Space A is considered indirectly conditioned.

SPACE B: The area weighted heat transfer coefficient to directly conditioned space is 75 Btu/hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (3 x 70 Btu/hr-°F) + 90 Btu/hr-°F = 300 Btu/hr-°F. Since the heat transfer coefficient from Space B to the conditioned space is less than the heat transfer coefficient from Space B to outside, Space B is considered unconditioned.

SPACE C: The area weighted heat transfer coefficient to directly conditioned space is (2 x 75 Btu/hr-°F = 150 Btu/hr-°F). The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (2 x 70 Btu/hr-°F) + 90 Btu/hr-°F = 230 Btu/hr-°F. Since the heat transfer coefficient from Space C to the conditioned space is less than the heat transfer coefficient from Space C to outside, Space C is considered unconditioned.

Example 1-16

Question

In a four-story building, the first floor is retail, second and third floors are offices, and the fourth floor is residential. Is the residential space high-rise or low-rise?

Answer

It is a high-rise residential space. Even though there is only one floor of residential occupancy, the building has four habitable stories, making it a high-rise building.

1.8 About the Energy Code

1.8.1 History

Section 25402 of the Public Resources Code

The Legislature adopted the Warren-Alquist Act (the act), which created the Energy Resources and Conservation Development Commission (California Energy Commission, or CEC) in 1975 to deal with energy-related issues and charged the CEC to adopt and maintain energy efficiency standards for new buildings. The first standards were adopted in 1978 in the aftermath of the Organization of Petroleum Exporting Countries (OPEC) oil embargo of 1973.

The act requires that the Energy Code be cost-effective "when taken in their entirety and amortized over the economic life of the structure."

The CEC is required to periodically update the standards. One hundred eighty (180) days after the approval of the standards, manuals must be published to support the Energy Code. . The Energy Code (Part 6) goes into effect along with the other Parts of the California Building Standards Code (Title 24) on the stautorily required triennial update cycle. The act directs local building permit jurisdictions to not approve permits until the building satisfies the requirements of the standards.

The first-generation standards for nonresidential buildings took effect in 1978. Second-generation standards took effect for offices, and retail and wholesale stores, in 1984 and 1985, respectively.

The next major revision occurred in 1992 when the requirements were simplified and consolidated for all building types. Major changes were made to lighting, building envelope, fenestration, and HVAC and mechanical requirements. Structural changes made in 1992 led the way for national standards in other states.

The standards went through minor revisions in 1995. In 1998, lighting power limits were reduced significantly because electronic ballasts and T-8 lamps were cost-effective and becoming commonplace in nonresidential buildings.

The California electricity crisis of 2000 resulted in rolling blackouts through much of the state. This crisis produced escalating energy prices at the wholesale market and in some areas in the retail market. The Legislature responded with Assembly Bill 970 (Ducheny, Chapter 329, Statutes of 2000), which required the CEC to update the Energy Code through an emergency rulemaking. This rulemaking was achieved within the 120 days required by the Legislature. The 2001 Standards (or the AB 970 Standards) took effect mid-2001. The 2001 Energy Code included requirements for high-performance windows throughout California, more stringent lighting requirements, and other changes.

The Public Resources Code was amended in 2002 through Senate Bill 5X (Machado, Chapter 852, Statutes of 2008) to expand the authority of the CEC to develop and maintain standards for outdoor lighting and signs. The Energy Code covered in this manual builds on the rich history of Nonresidential Energy Code in California and the leadership and direction provided by the California Legislature over the years.

The 2008 Energy Code was expanded to include refrigerated warehouses and steep-sloped roofs.

The 2013 Energy Code reflected many significant changes and expanded the scope. Some changes included fault detection and diagnostic devices, economizer damper leakage and assembly criteria, air handler fan control for HVAC systems, updates to the low-sloped cool roofs requirements for nonresidential buildings, and, for the first time, set minimum mandatory requirements for insulation in nonresidential buildings. Expanding the scope of the standards included newly regulated covered processes such as parking garage ventilation, process boiler systems, compressed air systems, commercial refrigeration, laboratory exhaust, data center (computer room) HVAC, and commercial kitchens.

The 2016 Energy Code was current with ASHRAE 90.1 national consensus standards. Changes were made to HVAC controls, indoor and outdoor lighting, advanced building control systems, and covered processes, including new requirements for elevators, escalators, and moving walkways.

The 2019 Energy Code updated the indoor and outdoor lighting requirements to assume the use of LED lighting, updated indoor air quality requirements, and expanded to include requirements for healthcare facilities for the first time.

For a detailed list of the changes to the 2022 Energy Code, see Section 1.5 of this chapter, or view our 2022 Building Energy Efficiency Standards Summary found at https://www.energy.ca.gov/sites/default/files/2021-08/CEC_2022_EnergyCodeUpdateSummary_ADA.pdf.

Example 1-17

Question

Does a LEED-certified building still need to meet the 2022 Energy Code?

Answer

Yes.

1.8.2 California Climate Zones

Since energy use depends partly upon weather conditions, the CEC established 16 climate zones representing distinct climates within California. These 16 climate zones are used with residential and the nonresidential standards. Information is available by zip code and in several formats (http://energy.ca.gov/maps/renewable/building_climate_zones.html).

Cities may occasionally straddle two climate zones. In these instances, the exact building location and correct climate zone should be verified before any calculations are performed. If a climate zone boundary line splits a single building, it must be designed to the requirements of the climate zone in which 50 percent or more of the building is contained.

Figure 1-1: California Climate Zones

Source: California Energy Commission

TABLE OF CONTENTS

2. Compliance and Enforcement

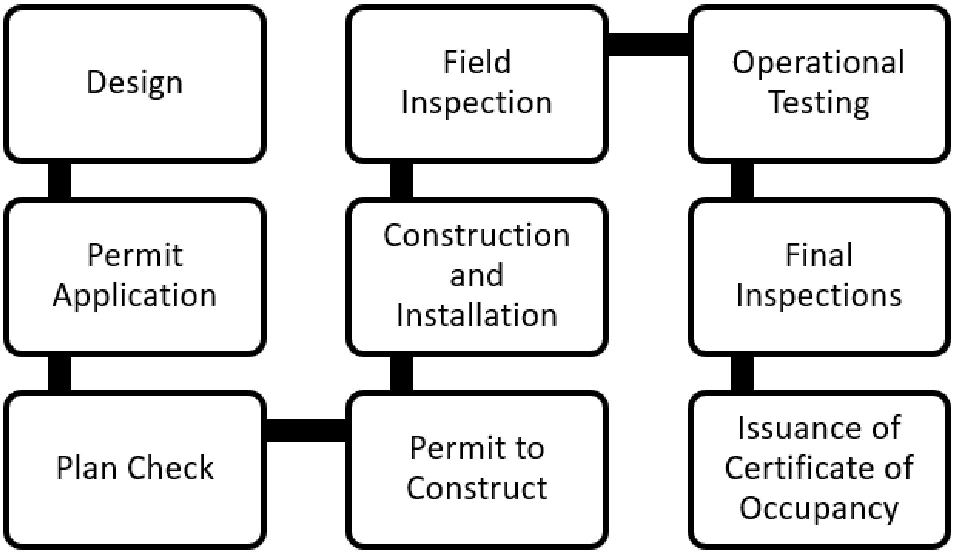
2.1 Overview

This chapter is organized as follows:

The California Building Standards Code is Title 24 of the California Code of Regulations and includes 12 parts covering all aspects of building construction regulations in California. The Building Energy Efficiency Standards (Energy Code) is Part 6 of Title 24. Primary responsibility for compliance with the Energy Code rests with the builder and building owner. The builder or building owner must demonstrate compliance with the Energy Code to an enforcement agency. The California Energy Commission (CEC) does not directly enforce the Energy Code. Enforcement agencies have the primary responsibility to issue a building permit for newly constructed buildings or additions and alterations to existing buildings and enforcement of all Parts of Title 24, including the Energy Code.

Most enforcement agencies are typically associated with a city or county government but can also include other agencies such as the California Division of the State Architect (for public schools). This chapter (Chapter 2) of the Nonresidential and Multifamily Compliance Manual is intended to show how compliance (by the builder) and enforcement (by the enforcement agency) of the Energy Code is achieved in the typical building project permitting process. Most enforcement agencies follow some version of the permitting process recommended by the International Code Council (ICC). Figure 2.1-1 shows an idealized version of the ICC permitting process.

Figure 2.1-1: Idealized International Code Council Permitting Process for Building Permit Applications



Source: California Energy Commission staff

To assist the builder, building owner, and enforcement agency, the CEC created four categories of compliance documents used to demonstrate compliance with the Energy Code for nonresidential construction projects and multifamily projects with four habitable stories or more:

- Certificates of compliance documents (NRCCs) are completed by the project proponent and submitted to the enforcement agency during the plan review phase.
- Certificates of installation (NRCI) are completed by the installing technician or contractor during construction and submitted to the enforcement agency during the project inspection phase.
- Certificates of acceptance (NRCA) are completed by the technician (may be in-house or third-party) who checks compliance of the installation with the Commission's acceptance testing requirements and submitted to the enforcement agency during the final inspection phase and prior to the enforcement agency issuing the certificate of occupancy. For lighting controls and mechanical system, the NRCA must be completed by a technician certified by a CEC-approved certification provider to perform the acceptance tests.
- Certificates of verification (NRCV, part of the CF3Rs) are required in some relatively rare instances. They are completed by an independent, third-party agent certified by a CEC-approved Home Energy Rating System (HERS) provider and submitted to the enforcement agency during the final inspection phase and prior to the enforcement agency issuing the certificate of

occupancy. Alternatively, the Certificate of verification can be waived if the related NRCA is completed by a certified Acceptance Testing Technician (ATT).

For residential construction projects, including multifamily projects with three habitable stories or less, the CEC created three categories of compliance documents for Energy Code compliance:

- Certificates of compliance (CF1R) are completed by the project proponent and submitted to the enforcement agency during the plan review phase.
- Certificates of installation (CF2R) are completed by the installing technician or contractor during construction and submitted to the enforcement agency during the project inspection phase.
- Certificates of verification (CF3R) are completed by an independent, third-party agent certified by a CEC-approved field verification and diagnostic testing provider and submitted to the enforcement agency during the final inspection phase and prior to the enforcement agency issuing the certificate of occupancy.

The independent, third-party agents responsible for completion of the certificates of verification are made available through the CEC’s Home Energy Rating System (HERS) program. The HERS program consists of providers, approved by the CEC to train, certify, and oversee HERS Raters, who perform specific tests on energy efficiency features as required by the Energy Code. The related compliance process requires participation from the architect, building designer, engineers, energy consultants, contractors, the owner, HERS Raters, and others. In this compliance process, the HERS Raters are the agents that are independent and third-party from the builders, contractors and HERS Providers.

The certified technician responsible for the NRCAs are made available through the CEC’s Acceptance Test Technician Certification Provider (ATTCP) program. Certified technicians are referred to as acceptance test technicians (ATTs) and are required to perform the NRCA acceptance tests for lighting controls and mechanical systems. Unlike HERS Raters, ATTs are not required to be independent, third-party agents from the builder. ATTs can (and often do) perform the installation work as well as acceptance testing of the lighting controls or mechanical systems.

This chapter describes the overall compliance and enforcement process and responsibilities throughout the permitting process. The scope of the Nonresidential and Multifamily Compliance Manual includes newly constructed buildings as well as addition and alterations to existing buildings. Building types covered in this manual include all of the following occupancy groups:

- Group A: Assembly, this occupancy is a used for gatherings such as civic, social, religious function, recreation, food/drink consumption, or waiting for transportation.

- Group B: Business, this occupancy is a used for functions such as an office or a professional or a service-type transaction.
- Group E: Educational, this occupancy is typically where six or more persons at any one time occupy a space for educational purposes through the twelfth grade.
- Group F: Factory and Industrial, this occupancy involves assembling, disassembling, fabricating, finishing, manufacturing, packaging, repair, and processing operations that would not be otherwise classified as a Group H or Group S occupancy.
- Group H: High Hazard, this occupancy includes manufacturing, processing, generation, or storage of materials that can constitute a physical or health hazard. Group H occupancies are classified into five high-hazard areas that identify the type of hazard for each group.
- Group I: Institutional, where care or supervision is provided to people who are or are not capable of self-preservation without physical assistance or in which people are detained for penal or correctional purposes or in which the liberty of the occupants is restricted.
- Group M: Mercantile, involving the display and sale of merchandise, stocking of goods, and is accessible to the public.
- Group S: Storage, this occupancy involves a building that is used for storage purposes.
- Group U: Utility and Miscellaneous, this occupancy involves a building or structure that is used as an accessory or miscellaneous use not classified as any other specific occupancy.
- Hotel/Motels have six or more guest rooms or a lobby serving six or more guest rooms, where the guest rooms are intended or designed to be used, or which are used, rented, or hired out to be occupied, or which are occupied for sleeping purposes by guests, and all conditioned spaces within the same building envelope. Hotel/motel also includes all conditioned spaces that are (1) on the same property as the hotel/motel, (2) served by the same central heating, ventilation, and air-conditioning system as the hotel/motel, and (3) integrally related to the functioning of the hotel/motel as such, including, but not limited to, exhibition facilities, meeting and conference facilities, food service facilities, lobbies, and laundries. Hotel/motel also includes:
  - Group R-1, sleeping units in this occupancy group are primarily transient in nature including vacation timeshare properties. This occupancy group is most often associated with hotels and motels.
  - Group R-2, sleeping units or more than two dwelling units where the occupants are primarily permanent. For example: convents, dormitories, nontransient hotels, or vacation timeshare properties.
  - The following types of Group R-3:

- Congregate residences for transient use
- Boarding houses of more than six guests
- Alcohol or drug abuse recovery homes of more than six guests.

Additionally, the Nonresidential and Multifamily Compliance Manual includes a chapter regarding multifamily buildings (Chapter 11). Multifamily buildings are considered separate from nonresidential buildings. The Energy Code defines multifamily buildings as a building of occupancy group R-2 (other than a hotel/motel building or timeshare property), R-3 (that is a nontransient congregate residence, other than boarding houses of more than six guests and alcohol or drug abuse recovery homes of more than six guests), or R-4, more than 5 people but no more than 16, excluding staff, who reside on a 24-hour basis where the occupants are in a supervised residential environment and receive custodial care.

2.1.1 Manufacturer Certification for Equipment, Products, and Devices

During the permit application development phase, certain equipment, products, and devices must be selected for installation or use that are certified to be compliant with the Energy Code. These items are identified on the NRCC or the CF1Rs or both and are verified during inspection by the enforcement agency.

The equipment, products, and devices must be certified to the CEC by the manufacturer that it meets requirements under the Energy Code. The CEC makes no claim that the listed equipment, products, or devices meet the indicated requirements or, if tested, will confirm the indicated results. Inclusion on these lists confirms only that a manufacturer certification has been submitted to and accepted by the CEC. See the CEC's website for additional information about the required information for manufacturers to certify products and for lists of certified products:

http://www.energy.ca.gov/title24/equipment_cert/

In nonresidential buildings, the following are examples of products that must be certified by the manufacturer:

- Air economizers
- Airflow measurement apparatus — forced air systems
- Airflow measurement apparatus — ventilation systems
- Airflow measurement apparatus — whole house fan systems
- Air-to-water heat pump systems
- Economizer fault detection and diagnostics
- Intermittent mechanical ventilation systems
- Low-leakage air-handling unit
- Occupant-controlled smart thermostats
- Demand-responsive control systems

- Ducted variable capacity heat pump
- Fault indicator display
- Battery and energy storage systems

2.1.2 HERS Program Compliance Document Registration

§10-103
Reference Residential Appendix RA2
Reference Joint Appendix JA7
Reference Nonresidential Appendix NA1 and NA2

The HERS program was developed by the CEC to help ensure compliance with the Energy Code for residential projects that need to include a HERS Rater to perform required field verification and diagnostic tests (HERS Verification). For nonresidential projects, a HERS Rater may be required to perform a verification in two instances: duct leakage tests (for single zone HVAC systems with ducts primarily located outside of conditioned space) and compact plumbing designs.

Registration of residential compliance documentation (CF1Rs, CF2Rs, CF3Rs, and NRCVs) is required for any residential construction project for which a CF3R is required (not all residential construction projects require a CF3R). In this manual, the low-rise multifamily projects are the only residential projects that would be required to use the HERS program.

All residential compliance documents (CF1Rs, CF2Rs, and CF3Rs) submitted to the registry must be certified and signed by the applicable responsible person (§10-103) and the author of the document. The data registry will assign a unique registration number to each document when completed and certification (by an electronic signature) is provided by all signatories. The data registry will retain the unique registered documents, which are available via secure internet access to authorized users. This availability allows authorized users to make paper copies of the registered documents for purposes such as submitting to the enforcement agency, posting copies in the field for inspections, and providing copies to the building owner.

Authorized users of the registry include energy consultants, builders, building owners, construction contractors and installers, HERS Raters, enforcement agencies, and the CEC. Authorized users are granted access rights to the electronic data associated with the projects under their direct or shared control.

Registration requirements are described in this chapter and elsewhere in this manual. Also, Reference Joint Appendix JA7 provides detailed descriptions of document registration procedures and individual responsibilities for registration of CF1Rs, CF2Rs, and CF3Rs. More Details regarding registration requirements for NRCVs are found in Reference Nonresidential Appendix NA1 and NA2.

2.2 Compliance Phases

2.2.1 Design Phase

The design phase for newly constructed buildings is significant and can extend for more than a year in some cases. In fact, many projects fail during the design phase. This phase sets the stage for the construction project, anything from a newly constructed nonresidential or multifamily building to additions or alterations of an existing building. The design, plans, and compliance documentation are initially developed in the design phase. While nonresidential and multifamily projects typically rely heavily on design professionals (architect, engineers, contractors, etc.), it is ultimately the responsibility of the project owner(s) to ensure that the project complies with all applicable requirements of the California Building Code — including the Energy Code. Energy Code compliance is demonstrated by completing the required NRCCs for nonresidential, hotel/motel, and high-rise multifamily projects; NRCCs and CF1Rs for low-rise multifamily projects.

In addition to issues concerning zoning, lot orientation, property line easement, and infrastructure, design professionals are responsible for California Building Code compliance as well as local ordinances. The obligation to comply with building codes and ordinances is based on professional and contractor licensing laws, the contract to perform work on the project, and the standard of care for workmanship. The contractor can attempt to shift their obligations for code-compliant plans to the owner and the architect or engineer. However, the contractor should make it a practice to review the plans and specifications for code compliance prior to entering into a contract. If the contractor finds inaccuracies and errors in the plans and specifications that are code violations, they should immediately notify the owner, architect, or engineer. Project owners would be well advised to include a contractor review of the design plans and compliance documents prior to submitting them to a enforcement agency for a permit to construct.

2.2.2 Building Commissioning

§10-103(a); §120.8

Building commissioning is both a general industry term and a defined term (with associated regulations in §120.8) within the Energy Code. Originally, the term "commissioning" came from the ship building industry, with the intent of that commissioning transferring to the concept of building commissioning. When a building is commissioned, it is intended to undergo a quality assurance process that begins during design and continues through construction, occupancy, and operations. Commissioning is intended to ensure that the newly constructed buildings perform initially as intended and that building staff are prepared to operate and maintain the systems and equipment to continue that performance.

The Energy Code defines "building commissioning" as a systematic quality assurance process that spans the entire design and construction process, including verifying and documenting that building systems and components are planned, designed, installed, tested, operated, and maintained to meet the owner's project requirements.

The CEC does not require certification to perform building commissioning for the Energy Code. Although a "commissioning agent" is not a defined term within the Energy Code, there are many professionals that are trained and certified by a variety of professional organizations to perform building commissioning. The CEC is aware of these certification programs but does not endorse them.

The Energy Code, Part 1, §10-103(a)1 does require that the person(s) reviewing and signing the commissioning compliance documents must be a licensed professional engineer or a licensed architect (as specified in the provisions of Division 3 of the Business and Professions Code). A licensed contractor that is representing services performed by or under the direct supervision of a licensed engineer or architect is also eligible to sign. The signatory is further restricted by §10-103(a)1 as follows:

- For buildings less than 10,000 square feet, this signatory may be the engineer or architect of record.
- For buildings greater than 10,000 square feet but less than 50,000 square feet, this signatory shall be a qualified in-house engineer or architect with no other project involvement or a third-party engineer, architect, or contractor.
- For buildings greater than 50,000 square feet and all buildings with complex mechanical systems (as defined by the Energy Code) serving more than 10,000 square feet, the signatory shall be a third-party engineer, architect, or contractor.

The square footage referenced in §10-103(a)1 refers to the total square footage of the project. This is an important distinction from the square footage used by the building commissioning triggers below.

Building commissioning (§120.8) applies to newly constructed nonresidential, hotel/motels, and high-rise multifamily buildings and is based on the square footage of the **nonresidential spaces** as opposed to the total square footage of these buildings. For example, the corridors, meeting rooms, lobbies, and other public spaces within a newly constructed hotel/motel or high-rise multifamily building count toward the nonresidential space, but the dwelling units themselves do not. Building commissioning does not apply to newly constructed low-rise multifamily buildings but is recommended as an industry best practice. Healthcare facilities are also not required to meet the Energy Code building commissioning requirements but must comply with Chapter 7 Safety Standards for Health Facilities of the California Administrative Code (Title 24, Part 1).

From §120.8, the explicit triggers for building commissioning are as follows:

- Newly constructed nonresidential buildings, including hotel/motels and high-rise residential buildings and excluding healthcare facilities, are required to comply with applicable requirements of §120.8.
- Such buildings with conditioned space of 10,000 square feet or more of nonresidential space are required to comply with the applicable requirements of §120.8(a) through §120.8(i).
- Such buildings with conditioned space of less than 10,000 square feet must comply with only §120.8(d) and §120.8(e).
- All building systems and components covered by Sections 110.0, 120.0, 130.0, and 140.0 are required to be included in the scope of the commissioning process, excluding those related solely to covered processes

CEC building commissioning requires the completion and documentation of the following items (§120.8[a] lists the coded sections within §120.8 that require compliance — §120.8[b] through §120.8[i]):

1. (§120.8[b]) Owner's or owner representative's project requirements (OPR)
    a. Required for projects with 10,000 square feet or more of conditioned nonresidential space
    b. OPR is the energy-related expectations and requirements of the building that are documented before the design phase of the project begins.
    c. Compliance documentation: 2022-NRCC-CXR-E, Table G.
2. (§120.8[c]) Basis of design (BOD)
    a. Required for projects with 10,000 square feet or more of conditioned nonresidential space
    b. BOD is a written explanation of how the design of the building systems and components meets the OPR and is completed at the design phase of the building project and updated as necessary during the design and construction phases. The BOD document at a minimum covers the following systems and components:
        i. Heating, ventilation, air conditioning (HVAC) systems and controls
        ii. Indoor lighting system and controls
        iii. Water heating systems and controls
        iv. Any other building equipment or system listed in the OPR
        v. Any building envelope component considered in the OPR
    c. Compliance documentation: 2022-NRCC-CXR-E, Table H
3. (§120.8[d]) Design Phase Design Review. The design reviewer is the signatory of the design review kickoff certificate(s) of compliance and construction document design review checklist certificate(s) of compliance.

   a. Required for all projects with conditioned nonresidential space
   b. Design review kickoff. During the schematic design phase of the building project, the owner or owner's representative, design team, and design reviewer must meet to discuss the project scope, schedule, and ways that the design reviewer will coordinate with the project team.
   c. Compliance documentation: 2022-NRCC-CXR-E, Table F
   d. Construction documents design review. The Construction Document Design Review Checklist Certificate of Compliance lists the items checked by the design reviewer during the construction document review.
   e. Compliance documentation: 2022-NRCC-CXR-E, Table I
4. (§120.8[e]) Commissioning measures shown in the construction documents
   a. Required for all projects with conditioned nonresidential space
   b. These documents are complete descriptions of all measures or requirements necessary for commissioning included in the construction documents (plans and specifications).
   c. Compliance documentation: 2022-NRCC-CXR-E, Table I
5. (§120.8[f]) Commissioning plan
   a. Required for projects with 10,000 square feet or more of conditioned nonresidential space
   b. Prior to permit issuance, a commissioning plan is completed to document how the project will be commissioned and is started during the design phase of the building project.
   c. Compliance documentation: 2022-NRCC-CXR-E, Table-J
6. (§120.8[g]) Functional performance testing
   a. Required for projects with 10,000 square feet or more of conditioned nonresidential space
   b. Functional performance tests demonstrate the correct installation and operation of each component, system, and system-to-system interface in accordance with the acceptance test requirements in the Energy Code.
   c. Compliance documentation: 2022-NRCC-CXR-E, Table-K
7. (§120.8[h]) Documentation and training
   a. Required for projects with 10,000 square feet or more of conditioned nonresidential space
   b. This is a systems manual and systems operations training to be provided prior to the owner or owner's representative postconstruction.
   c. Compliance documentation: 2022-NRCC-CXR-E, Table-L

8. (§120.8[i]) Commissioning report
   a. Required for projects with 10,000 square feet or more of conditioned nonresidential space
   b. This is a complete report of commissioning process activities undertaken through the design, construction, and reporting recommendations for postconstruction phases of the building project and is provided to the owner or owner's representative.
   c. Compliance documentation: 2022-NRCC-CXR-E, Table-M

The compliance document NRCC-CXR-E is the bare minimum that the Energy Code requires. Certified commissioning agents will typically provide far more support and organization to a construction project as a matter of their certification training and industry best practices. The CEC encourages but does not require a building commissioning process and documentation beyond the minimum requirements of the Energy Code §120.8.

2.2.2.1 Integrated Design

Integrated design is not required by the Energy Code but is a recognized industry best practice related to building commissioning. "Integrated design" is the consideration that brings the design of all related building systems and components together. It brings together the multiple disciplines involved in designing a building or system and reviews the related recommendations as a whole. It recognizes that the recommendations for each discipline have an impact on other aspects of the building project. This approach allows for optimization of building performance and cost.

For example, often HVAC systems are designed without regard for lighting systems, or lighting systems are designed without consideration of daylighting opportunities.

The architect, mechanical engineer, electrical engineer, contractors, and other team members each have their scope of work and often pursue the work without adequate communication and interaction with other team members. This lack of communication can result in improper system sizing or systems that are optimized for nontypical conditions.

Even a small degree of integration provides some benefit, allowing professionals working in various disciplines to take advantage of design opportunities that are not apparent when they are working in isolation. This can also point out areas where trade-offs can be implemented to enhance energy efficiency. Design integration can avoid redundancy or conflicts with aspects of the building project planned by others. The earlier that integration is introduced in the design process, the greater the benefit that can be expected.

2.2.3 Permit Application

§10-103(a); §10-103(a)2

2.2.3.1 Certificates of Compliance

NRCCs (nonresidential certificates of compliance) are required for newly constructed buildings, as well as additions and alterations to existing buildings. The design team (architects, engineers, designers, or other specialty contractors) is responsible for ensuring that the building designs comply with the California Building Standards Code, including the Energy Code. Once the design team has settled on a code-compliant design, it is required (§10-103[a]) to document the compliance with the Energy Code by completing and signing the NRCCs. Table 2.2-1 lists all the possible NRCCs that the design team may need to use.

Table 2.2-1 Certificates of Compliance

Certificate of Compliance	Certificate Name
NRCC-CXR-E	Building Commissioning
NRCC-ELC-E	Electrical Power Distribution
NRCC-ENV-E	Building Envelope
NRCC-LTI-E	Indoor Lighting
NRCC-LTO-E	Outdoor Lighting
NRCC-LTS-E	Sign Lighting
NRCC-MCH-E	Mechanical Systems
NRCC-PLB-E	Water-Heating Systems
NRCC-PRC-E	Covered Process
NRCC-SRA-E	Solar-Ready Areas

Source: California Energy Commission staff

These NRCCs were available from the CEC (via Energy Code Ace) for 2019 Energy Code compliance and were designed to be dynamic forms that would expand, and contract as needed to describe the proposed project. The CEC adopted the Energy Code Ace Virtual Compliance Assistance (VCA) tool instead of the individual NRCCs for 2022 Energy Code compliance.

The VCA tool uses an interrogatory method to determine what NRCCs are necessary for a specific project, complete the necessary NRCCs based on the information entered, and make them ready for review and signature. The VCA can make recommendations only for projects that use the prescriptive path. (See Chapter 1 of the Nonresidential and Multi-Family Compliance Manual.) To complete the necessary NRCCs for projects using the performance path, the design team must use a CEC-approved compliance model. The CEC maintains a list of these approved compliance models on the 2022 Building Energy Efficiency Standards Approved Computer Compliance Programs website. The compliance model will create an NRCC-PRF-01 form with the necessary information for the design team to complete the required NRCCs.

Regardless of what compliance path or what compliance tool the design team uses, as the applicant applying for a permit to construct with an enforcement agency, the design team is solely responsible for completing the correct NRCCs and designing a code-compliant project. Once the design team has completed the required project design details, NRCCs, and any other documentation required by the enforcement agency, it can begin the permit application phase by submitting a complete application for a permit to construct to the enforcement agency.

All applicable NRCCs must be signed by a document author and a responsible person. While there are no requirements for the document author, the responsible person must be eligible under Division 3 of the Business and Professions Code to accept responsibility for the building design or system design identified on each NRCC (§10-103[a]). For example, a technician may complete the NRCC-MCH-E, but only the engineer of record (that was on the design team) can review and sign as the responsible person. The responsible person can also act as the document author. Once completed, reviewed by the responsible person, and signed, each NRCC must be included in the application for permit to construct to the enforcement agency.

2.2.3.2 Commissioning Design Review

For newly constructed buildings, the design review kickoff and construction document design review certificate of compliance (NRCC-CXR-E) must be signed by the approved design reviewer, as specified in §10-103(a)1 and submitted for approval by the enforcement agency with the permit application. This document is required for all newly constructed projects with conditioned nonresidential space regardless of the compliance method used (prescriptive or performance). To demonstrate compliance, all projects are required to complete the NRCC-CXR-E. The building owner, representative, design engineer and design reviewer must all sign and date the NRCC-CXR-E once the design review has been completed. Contractors accepting the responsibilities of the engineer under the provision of the Business and Profession Code may sign the documents in place of the design engineer. See Chapter 13 of for more details regarding building commissioning.

2.2.3.3 Preparation and Incorporation Onto the Plans

The length and complexity of the NRCCs may vary depending on the size and complexity of the building(s) or system(s) that are being permitted, regardless of which compliance method is used. The NRCCs are commonly prepared by an energy consultant or energy compliance professional (documentation author) although this is not a requirement of the Energy Code, just an industry practice. An energy consultant should be knowledgeable about the Energy Code and can benefit the design team by offering advice for the selection of the compliance method (prescriptive or performance), compliance tools (VCA or a compliance model or both), and the selection of the energy features used for compliance with the Energy Code. An energy consultant may also provide recommendations for the most cost-effective mix of building energy features for the design.

The Administrative Regulations, §10-103(a)2, require that the NRCCs and any applicable supporting documentation be submitted with the permit application and that the NRCCs be incorporated into the building plans. Many enforcement agencies require that all the energy compliance documents be incorporated electronically onto the building plans. This incorporation enables the plans examiner to verify that the building or system design specifications shown on construction documentation are consistent with the energy features specified on the NRCCs. Samples of the CEC-approved documents are in Appendix A of this manual. A listing of certificate of compliance documents is available in Table 2.1-1.

2.2.3.4 HERS Data Registry — Compliance Document Registration

High-rise multifamily buildings, some nonresidential duct leakage testing, and plumbing designs are required to register compliance documents with the HERS data registry. The registration requires the builder or designer to become an authorized user of the HERS data registry and submit the required CF1Rs and an electronic signature to an approved HERS data registry to produce a completed, dated, and signed electronic CF1R that is retained by the HERS data registry.

Examples of authorized users of the HERS data registry may include energy consultants, builders, building owners, construction contractors and installers, enforcement agencies, the CEC, and other parties to the compliance and enforcement process that the documents are designed to support. Authorized users of the HERS data registry will be granted read/write access rights to only the electronic data that pertains to their project(s).

2.2.4 Plan Check

§10-103(d)1

2.2.4.1 Plans and Specifications

Enforcement agencies are required to check submitted building plans to determine compliance with the California Building Code, including the Energy Code. Vague, missing, or incorrect information on the NRCCs and CF1Rs may be identified by the plans examiner as requiring correction by the permit applicant. The permit applicant would then resubmit the revised building plans and specifications. When the permit applicant submits comprehensive, accurate, clearly defined building plans and specifications, the submission may help speed plan review. Because the enforcement agency bears responsibility for code enforcement, only it may pursue corrections to approved plans and compliance documents.

During plan review, the enforcement agency must verify that the building design details specified on the construction documents conform to the applicable energy code features information specified on the submitted NRCCs and CF1Rs. This conformance is necessary since materials purchasing personnel and building construction craftsmen in the field may rely solely on a copy of the building plans and specifications for direction in performing their responsibilities.

2.2.4.2 Energy Plan Review

The enforcement agency is responsible for verifying that all required NRCCs and CF1Rs have been submitted for plan review, are consistent with the submitted plans, and do not contain errors. When the compliance documents are produced by a CEC-approved compliance software application, the VCA, or the HERS data registry, it is unlikely that there will be computational errors on the NRCCs or CF1Rs. Some examples of how the plans examiner will verify that the energy efficiency features detailed on the NRCCs are consistent with the building plans include:

1. Verifying the lighting fixtures and associated wattages, lighting controls, and so forth from NRCC-LTI-E are consistent with the electrical plans in a lighting schedule, lighting fixture legend for the floor plan, etc.
2. Verifying the window and skylight U-factor and SHGC values from NRCC-ENV-E are consistent with the structural/architecture plans in a window/skylight schedule, window/skylight legend for the floor plan, and so forth.
3. Verifying the wall, floor, and roof/ceiling insulation R-values from the NRCC-ENV-E are consistent with the structural/architecture plans in a framing plan, structural details, and so forth.
4. Verifying the HVAC equipment SEER, EER, AFUE, and other efficiency values from the NRCC-MCH-E are consistent with the mechanical plans in an equipment schedule.

Note: The enforcement agency should clearly articulate to the builder/designer the acceptable methods of specifying energy features on the building plans for approval.

2.2.5 Permit to Construct

§10-103(d)1

After the plans examiner has reviewed and approved the building plans, specifications, NRCCs, and CF1Rs for the project, the enforcement agency may issue a building permit at the builder's request. Issuance of the building permit is the first significant milestone in the compliance and enforcement process. The building permit is the green light for the contractor to begin work. In many cases, building permits are issued in phases. Sometimes, there is a permit for site work and grading that precedes the permit for actual construction. In large office, multifamily, or institutional buildings, the permit may be issued in phases, such as site preparation or structural steel.

2.2.6 Construction and Installation

§10-103(a)3

2.2.6.1 Certificates of Installation

As construction begins and progresses, the installing contractor, general contractor, specialty contractor, or other qualified person is required to complete the NRCIs (Nonresidential Certificates of Installation) relevant for each energy efficiency feature being installed. The NRCIs (or CF2Rs) document that the installing contractor is aware of the requirements of the NRCC (or CF1R) and the Energy Code and that the actual construction and installation meet these requirements.

NRCIs are required to be completed and submitted to document compliance of the installation of regulated energy efficiency features such as windows and skylights, water heater, plumbing, HVAC ducts and equipment, lighting fixtures and controls, and building envelope insulation. The licensed contractor responsible for the building construction or the installation of a regulated energy efficiency feature must ensure the work is done in accordance with the approved building plans, specifications, and NRCC (or CF1R) for the project. The installing contractor (and document author) must sign the NRCI.

The responsible persons must also sign the NRCI and are expected to verify that the installed features, materials, components, or manufactured devices for which they are responsible conform to the building plans, specifications, NRCC (or CF1R) approved by the enforcement agency for the project. A copy of the completed, signed, and dated NRCI must be posted at the building site for review by the enforcement agency before the final project inspection.

If construction of any regulated portion of the project will be impossible to inspect once subsequent construction is completed, the enforcement agency may require the NRCI to be posted upon completion of that feature/portion of the project and before completion of any subsequent construction.

A listing of NRCI documents is provided in Table 2.2-2. A copy of the NRCIs must be included with the documentation the builder provides to the building owner at occupancy as specified in §10-103(b). The NRCIs are available through the VCA tool, and the CF2R is available through a HERS data registry. Both the NRCI and CF2R are linked to the NRCCs and CF1Rs, respectively. The NRCI/CF2Rs identify each energy efficiency feature that the contractor must install and provides a check box (if that exact feature is installed). If the feature is changed out for another feature, the NRCI/CF2R provide data entry fields for the new feature and will automatically indicate if the change needs to be approved by the enforcement agency.

Table 2.2-2: Nonresidential Certificate of Installation Documents

Certificate of Installation	Description
NRCI-LTI-E	Indoor Lighting
NRCI-LTO-E	Outdoor Lighting
NRCI-LTS-E	Sign Lighting
NRCI-ENV-E	Envelope
NRCI-SRA-E	Solar-Ready
NRCI-ELC-E	Electrical
NRCI-PLB-E	Plumbing
NRCI-MCH-E	Mechanical
NRCI-PRC-E	Covered Processes

Source: California Energy Commission staff

2.2.6.2 Change Orders

A "change order" is an industry term for a formal amendment to a construction contract that changes the contractor's scope of work. Not all changes to a construction project result in a formal change order. In many instances, the project owner can change the scope of work without a formal agreement. Most change orders modify the work, materials, or time to complete the work. For there to be a valid change order, the owner and contractor must both agree on all terms. Change orders exist because construction plans, although very detailed, cannot possibly anticipate every nuance or issue that may arise on a construction project. Some change orders will affect the plans approved by the enforcement agency and will require a separate approval. For example, changing the finish on an interior wall is unlikely to affect the approved plans, but adding or removing a window will.

For the energy efficiency features recorded on the approved NRCCs and CF1Rs, generally any change that reduces the energy efficiency will require a new NRCC or CF1R to be completed, signed, submitted (to the enforcement agency), and approved. These actions may also result in a special inspection by the enforcement agency. For example, switching to more efficient lighting will not likely result in a change order that is required to be approved, but changing which lights are daylighting-controlled will.

To help track what change orders should result in an enforcement agency approval, the CEC requires that the installing contractor complete the NRCIs and CF2Rs (for low-rise multifamily) using the VCA tool or the HERS data registry. If the enforcement agency approval is required for the change order, the responsible person must update and resubmit the affected NRCC or CF1R or both to the enforcement agency.

However, the automatic evaluation from the VCA tool or the HERS data registry or both are advisory. It is still the responsibility of the builder and building owner to determine if a change order needs to be approved by the enforcement agency regardless of the VCA tool or HERS data registry. Additionally, many enforcement agencies have a stricter policy when it comes to change orders and want them all submitted for review and possible approval regardless of the scope of the change.

2.2.7 Operational Testing

§10-103(a)4; §10-103.1; §10-103.2

Operational testing is part of the competency of workmanship that any installing contractor will perform to verify that their own work is up to industry standards and complies with the project design and California Building Standards Code (including the Energy Code). Formal operational testing is typically referred to as *acceptance testing* or *acceptance criteria verification*. The Energy Code requires specific acceptance testing (performed by the installing contractor) for lighting controls, HVAC controls, air distribution ducts, envelope features, and special purpose equipment, referred to as *covered processes*. However, the Energy Code acceptance testing procedures do not alleviate the installing contractor from performing any manufacturer required startup and commissioning tests for the installed energy efficiency feature. Certified technicians who conduct acceptance testing for lighting and mechanical systems are required by to be trained and certified by a CEC-approved Acceptance Test Technician Certification Provider (ATTCP). These certified technicians are referred to as *acceptance test technicians* (ATTs) The CEC verifies that the ATTCP provides the required classrooms and hands-on training to perform the required acceptance tests and complete the required documentation (§10-103.1 or §10-103.2). Builders and installers will need to ensure that an ATT conducts the required acceptance testing and completes the required NRCAs (Nonresidential Certificates of Acceptance) for lighting controls and mechanical systems. For this purpose, the ATTCPs provide publicly available lists of ATTs certified by the ATTCP. Enforcement agency field inspectors can verify that the submitted NRCAs are signed by an ATT using the same public lists and by inspection of the NRCA itself. Each NRCA is watermarked by the ATTCP that certified the ATT for authentication. The NRCA itself can also be verified by the ATTCP as valid by contacting the ATTCP by phone to email. The CEC keeps a link to all ATTCP at its ATTCP-Website (https://www.energy.ca.gov/programs-and-topics/programs/acceptance-test-technician-certification-provider-program/acceptance). Table 2.2-3 lists the Energy Code required NRCAs and indicates which are to be completed by ATTs through the ATTCP program. For more information of the ATTCP program, see Chapter 14 of the Nonresidential and Multi-Family Compliance Manual.

Table 2.2-3: Nonresidential Certificate of Acceptance

Certificate of Acceptance	Description	ATTCP Required
NRCA-ENV-02-A	Envelope – Fenestration	No
NRCA-ENV-03-A	Envelope – Daylight PAFs	No
NRCA-LTI-02-A	Lighting Controls - Shutoff	Yes
NRCA-LTI-03-A	Lighting Controls – Daylighting	Yes
NRCA-LTI-04-A	Lighting Controls – Demand Response	Yes
NRCA-LTI-05-A	Lighting Controls – Institutional Tuning	Yes
NRCA-LTO-02-A	Lighting Controls – Outdoor	Yes
NRCA-MCH-02-A	Mechanical – Outdoor Air	Yes
NRCA-MCH-03-A	Mechanical – Constant Volume	Yes
NRCA-MCH-04-A	Mechanical – Duct Leakage (ATT)	Yes
NRCA-MCH-05-A	Mechanical – Economizer	Yes
NRCA-MCH-06-A	Mechanical – Demand Control	Yes
NRCA-MCH-07-A	Mechanical – Supply Control	Yes
NRCA-MCH-08-A	Mechanical -Valve Leakage	Yes
NRCA-MCH-09-A	Mechanical – Supply Water	Yes
NRCA-MCH-10-A	Mechanical – Hydronic System	Yes
NRCA-MCH-11-A	Mechanical – Demand Shed Control	Yes
NRCA-MCH-12-A	Mechanical – FDD Package Direct	Yes
NRCA-MCH-13-A	Mechanical – FDD AHU/ZTU	Yes
NRCA-MCH-14-A	Mechanical – Energy Storage	Yes
NRCA-MCH-15-A	Mechanical – Thermal Energy Storage	Yes
NRCA-MCH-16-A	Mechanical – Supply Air Temp.	Yes
NRCA-MCH-17-A	Mechanical – Condenser Water Temp.	Yes
NRCA-MCH-18-A	Mechanical — EMCS	Yes
NRCA-MCH-19-A	Mechanical – Occupancy Sensor	Yes
NRCA-MCH-20a-A	Mechanical – Multi-Family Dwelling Inspection	Yes
NRCA-MCH-20b-A	Mechanical – MF Kitchen Exhaust	Yes

Certificate of Acceptance	Description	ATTCP Required
NRCA-MCH-20c-A	Mechanical – MF IAQ System	Yes
NRCA-MCH-20d-A	Mechanical – MF Dwelling HRV/ERV System	Yes
NRCA-MCH-21-A	Mechanical – MF Dwelling Leakage	Yes
NRCA-MCH-22-A	Mechanical – MF Duct Leakage	Yes
NRCA-MCH-23-A	Mechanical – MF HRV/ERV Verification	Yes
NRCA-PRC-01-F	Covered Process – Compressed Air	No
NRCA-PRC-02-F	Covered Process – Kitchen Exhaust	No
NRCA-PRC-03-F	Covered Process – Garage Exhaust	No
NRCA-PRC-04-F	Covered Process – Refrigerated Warehouse Motor Controls	No
NRCA-PRC-05-F	Covered Process – RW Evaporator Controls	No
NRCA-PRC-06-F	Covered Process — RW Condenser Controls	No
NRCA-PRC-07-F	Covered Process — RW Compressor	No
NRCA-PRC-08-F	Covered Process - RW Underslab Hearing	No
NRCA-PRC-12-F	Covered Process – Elevator Lighting and Ventilation	No
NRCA-PRC-13-F	Covered Process – Escalator Speed Control	No
NRCA-PRC-14-F	Covered Process – Lab Exhaust	No
NRCA-PRC-15-F	Covered Process – Fume Hood	No
NRCA-PRC-16-F	Covered Process – Adiabatic Condenser	No

Source: California Energy Commission

2.2.8 HERS Verification — Certificate of Field Verification and Diagnostic Testing

When single-zone, constant-volume space-conditioning systems (1) serving less than 5,000 ft² of floor area and (2) having more than 25 percent of the system surface duct area are located in unconditioned space, duct sealing is prescriptively required by §140.4(l) for newly constructed buildings and §141.0(b)2C, D, and E for HVAC alterations. A HERS Verification of the duct system must be conducted by a certified

HERS Rater to verify that the air distribution duct leakage of the system is within specifications required by the Energy Code. The HERS Verification is performed on each duct system or on a sample (one in seven) of duct systems. For example, a series of buildings on a project site where the contractor is installing new HVAC systems (qualifying as indicated above) would require that the associated ducts be tested for leakage (limited to 15 percent of the system air volume). The installing contractor with an ATT certification can perform and document the duct leakage test (NRCA-MCH-04-A) and place seven of the completed NRCAs in a group. A HERS Rater then selects of the NRCAs in the group at random and performs the same acceptance test. The HERS Rater then records only the HERS Verification that they performed in the HERS data registry.

As an alternative for the contractor or builder (if approved by the enforcement agency), an ATT may perform and document the duct leakage test (NRCA-MCH-04-A) for each NRCA without a separate verification by a HERS Rater. The ATT must record the duct test in the ATTCP database tracking system. In either case, each duct system must be tested, either by the contractor or an ATT.

2.2.9 Final Inspection by the Enforcement Agency and Issuance of the Certificate of Occupancy

§10-103(d)2

Local enforcement agencies inspect all new buildings and systems to ensure conformance with applicable codes and standards. The inspector may require that corrective action be taken to bring the construction/installation into compliance. Thus, the total number of inspection visits and the timing of the inspections that may be required before passing the final inspection may depend on the size and complexity of the building or system.

Enforcement agencies withhold issuance of a final certificate of occupancy until all compliance documentation is submitted, certifying that the specified systems and equipment conform to the requirements of the approved design and Energy Code. All certificates of HERS verification must be registered copies from an approved HERS data registry.

2.2.10 Certificate of Occupancy

The final step in the permitting process is the certificate of occupancy is issued by the enforcement agency. This is the green light for the building to be occupied. Although a developer may lease space before the issuance of the certificate of occupancy, the tenant cannot physically occupy the space until the enforcement agency issues the certificate of occupancy.

2.2.11 Occupancy – Compliance, Operating, and Maintenance Information

§10-103(b)

At the occupancy phase, the general contractor or design team or both are required to provide the owner with copies of the energy compliance documents, including NRCCs, CF1Rs, NRCIs, CF2Rs, NRCAs, CF3Rs, and any HERS verifications. Documents for the construction/installation, operating, maintenance, ventilation information and instructions for operating and maintaining the features of the building efficiently are also included.

2.2.12 Compliance Documentation

Compliance documentation includes the documents, reports, and other information that are submitted to the enforcement agency with an application for a building permit. Compliance documentation also includes documentation completed by the installing contractor, engineer/architect of record, owner's agent, or certified technician to verify that certain systems and equipment have been correctly installed and commissioned. Compliance documentation will also include reports and test/inspection results by HERS Raters when duct sealing/leakage testing is required unless performed by an ATT.

Each portion of the applicable compliance documentation must be completed and/or submitted during:

1. The building permit phase (NRCCs, CF1Rs).
2. The construction phase (NRCIs, CF2Rs).
3. The acceptance testing and HERS verification phases (NRCAs, CF3Rs).
4. The final inspection phase (all compliance documents include building commissioning documents).

All submitted compliance documentation is required to be compiled by the builder or general contractor. A copy of the compliance documentation is required to be provided to the building owner so that the end user has information describing the energy features installed in the building.

2.3 HERS Providers

http://www.energy.ca.gov/HERS/

The CEC approves HERS Providers, subject to the CEC's HERS Regulations (Title 20, Chapter 4, Article 8, Sections 1670 through 1675). Approved HERS Providers are authorized to train and certify HERS Raters and are required to maintain quality control over HERS verifications. The CEC maintains a list of approved HERS Providers on the CEC-HERS Provider website (https://www.energy.ca.gov/programs-and-topics/programs/home-energy-rating-system-hers-program/home-energy-rating-system).

The HERS Provider must maintain a HERS data registry that incorporates an website-based user interface that has functionality to accommodate the needs of the authorized users of the data registry who must participate in administering HERS compliance, document registration, and Energy Code enforcement.

The HERS data registry must receive and record information to identify and track energy efficiency features that require HERS Verification in a specific building/system and must be capable of determining compliance based on the information from the results of testing or verification procedures input to the registry for the building/system. When the compliance requirements are met, the HERS data registry must make a unique registered certificate of field verification and diagnostic testing available to enforcement agencies, builders, building owners, HERS Raters, and other interested parties to show compliance with the document submittal requirements of §10-103. The HERS data registry must have the capability to facilitate electronic submittal of the registered CF3Rs of an CEC document repository for retention of the certificates for use in enforcing the regulations.

The HERS Provider must make available (via phone or internet communications) a way for building officials, builders, HERS Raters, and other authorized users of the HERS data registry to verify the information displayed on copies of the submitted certificate. Refer to Reference Nonresidential Appendix NA1 Residential Appendix RA1-4 and Reference Joint Appendix JA7 for additional information on the HERS Provider's role and responsibilities.

An approved HERS Provider is also to be approved as a registration provider and facilitate documentation registration for nonresidential buildings and projects.

2.3.1 HERS Raters

A CEC-approved HERS Provider certifies the HERS Rater to perform the field verification and diagnostic testing that may be required to demonstrate and document compliance with the Energy Code. HERS Raters receive training in diagnostic techniques and building science as part of the certification process administered by the HERS Provider.

If the documentation author who produced the CF1R documentation for the building is not an employee of the builder or subcontractor, the documentation author for the building may also perform the responsibilities of a HERS Rater, provided the documentation author has met the requirements and has been certified as a HERS Rater by an approved HERS Provider.

The HERS Rater is responsible for:

- Conducting the field verification and diagnostic testing of the air distribution ducts.
- Transmitting all required data describing the results to a HERS Provider data registry.
- Confirming that the air distribution ducts conform to the design detailed on the building plans and specifications and the mechanical certificate of compliance (NRCC-MCH-E) is approved by the enforcement agency for the building.
- Verifying that the information on the certificates of installation and certificates of acceptance are consistent with the certificates of compliance.

- Performing the Verification (CF3R) and registering the results with the HERS data registry.

The results from the HERS verification are registered to the HERS data registry, including failures. If the results indicate compliance, the HERS data registry will make available a registered copy of the CF3R. A copy must be posted at the building site for review by the enforcement agency, made available for all applicable inspections, and included with the documentation that the builder provides to the building owner at occupancy as specified in §10-103(b).

A listing of Certificate of Field Verification and Diagnostic Testing documents (NRCVs) is available in Table 2.3-1. The certificate of field verification and diagnostic testing documents submitted to the enforcement agency to demonstrate compliance shall conform to a format and informational order and content approved by the CEC. (See §10-103[a]1A.) Samples of the CEC-approved documents are in Appendix A.

Table 2.3-1: Certificate of Verification Documents

Documents Name	Energy Code Reference	Reference Nonresidential Appendix
NRCV-MCH-04-H Air Distribution System Leakage Diagnostic	§10-103(a)5; §140.4(l); §141.0(b)2C, D, and E	NA1; NA2
NRCV-PLB-21-H High-Rise Multifamily Central Hot Water System Distribution	§140.5; §150.1(c)8	RA3.6;RA4.4
NRCV-PLB-22-H High-Rise Single Dwelling Unit Hot Water System Distribution	§140.5; §150.1(c)8	RA3.6;RA4.4

Source: California Energy Commission staff

2.3.2 Verification, Testing, and Sampling

At the builder's option, HERS verification is completed either for each constant-volume, single-zone, space-conditioning unit in the building or for a sample from a designated group of units. HERS verification uses the diagnostic duct leakage from the fan pressurization of ducts procedure in Reference Nonresidential Appendix NA2. If the builder chooses the sampling option, the applicable procedures described in NA1.6.1, NA1.6.2, and NA1.6.3 are followed.

The builder or subcontractor will provide a copy of the NRCCs signed by the principal designer/owner and a copy of the NRCIs to the HERS Rater, as required in NA1.4. Before completing the HERS verification, the HERS Rater confirms that the NRCIs and NRCAs have been completed as required and show compliance consistent with the NRCCs.

If the HERS verification determines that the requirements for compliance are met, the HERS Rater transmits the test results to the HERS data registry, whereupon the HERS Provider makes a copy of the registered CF3R for the HERS Rater, the builder, the enforcement agency, and other authorized users of the data registry. Printed copies, electronic or scanned copies, and photocopies of the completed, signed, and registered certificate of field verification and diagnostic testing are allowed for document submittals, subject to verification that the information on the copy conforms to the registered document information on file in the provider data registry for the space-conditioning unit.

The HERS Rater provides copies of the HERS verification to the builder and posts a copy of the CF3R at the building site for review by the enforcement agency in conjunction with requests for inspection.

The HERS Provider makes available (via phone or internet communications) a way for enforcement agencies, builders, and HERS Raters to verify that the information displayed on copies of the CF3R conform to the registered document information on file in the HERS data registry.

2.3.3 Initial Model Field Verification and Diagnostic Testing

The HERS Rater can test the first constant, single-zone, space-conditioning unit of each building. This initial testing allows the builder to identify and correct any potential duct installation and sealing flaws or practices before other units are installed. If the HERS verification determines that the requirements for compliance are met, the HERS Rater transmits the test results to the HERS data registry.

2.3.4 Resampling, Full Testing, and Corrective Action

"Resampling" refers to the procedure that requires testing of additional units within a sample group when the selected sample unit within a group fails to comply with the HERS verification requirements. When a failure is encountered during sample testing, the failure shall be entered into the provider's data registry. Corrective action shall be taken, and the unit shall be retested to verify that corrective action was successful. Corrective action and retesting on the unit shall be repeated until the testing indicates compliance and the results have been entered into the HERS data registry.

In addition, the HERS Rater conducts resampling to assess whether the first failure in the group is unique or if the rest of the units in the group are likely to have similar failings. The HERS Rater randomly selects for resampling one of the remaining untested units in the group for testing of the feature that failed. If testing in the resample confirms that the requirements for compliance credit are met, then the unit with the failure shall not be considered an indication of failure in the other units in the group. The HERS Rater transmits the resample test results to the HERS data registry for each of the remaining units in the group, including the dwelling unit that was resampled.

If field verification and diagnostic testing in the resample result in a second failure, the HERS Rater must enter the second failure into the HERS data registry and report it to the builder and enforcement agency. Multifamily dwelling units in the group must thereafter be tested. The builder will take corrective action in all space-conditioning units in the group that have not been tested. In cases where corrective action would require destruction of building components, the builder may choose to reanalyze compliance and choose different features that will achieve compliance. In this case, a new CF1R is registered to the HERS data registry and a copy submitted to the enforcement agency and HERS Rater. The HERS Rater conducts HERS verification for each of these space-conditioning units to verify that problems have been corrected and the requirements for compliance have been met. Upon verification of compliance, the HERS Rater enters the test results into the HERS data registry, whereupon a copy of the CF3R for each unit in the group is made available to the HERS Rater, the builder, the enforcement agency, and other authorized users of the HERS data registry.

The HERS Provider files a report with the enforcement agency explaining all action taken (including field verification, diagnostic testing, and corrective action) to bring into compliance units for which full testing has been required. If corrective action requires work not specifically exempted by the California Mechanical Code or the California Building Code, the builder shall obtain a permit from the enforcement agency before commencing any of the work.

2.3.5 Third-Party Quality Control Program (TPQCP)

The CEC may approve Third-Party Quality Control Programs (TPQCP) that serve some of the functions of HERS Raters for field verification but do not have the authority to sign compliance documentation as a HERS Rater. Third-Party Quality Control Programs:

A. Provide training to installers, participating program installing contractors, installing technicians, and specialty TPQCP subcontractors regarding compliance requirements for features for which diagnostic testing and field verification are required.

B. Collect data from participating installers for each installation completed for compliance credit.

C. Perform data checking analysis of information from diagnostic testing performed on participating TPQCP contractor installation work to evaluate the validity and accuracy of the data and independently determine whether compliance has been achieved.

D. Provide direction to the installer to retest and correct problems when data checking determines that compliance has not been achieved.

E. Require resubmission of data when retesting and correction are directed.

F. Maintain a database of all data submitted by the participating TPQCP contractor in a format that is acceptable and made available to the CEC upon request.

The HERS Provider must arrange for the services of an independent HERS Rater to conduct field verification and diagnostic testing of the installation performed by the participating TPQCP contractor. If group sampling is used for HERS verification compliance for jobs completed by a participating TPQCP contractor, the sample from the group that is tested for compliance by the HERS Rater may be selected from a group composed of up to 30 units for which the TPQCP contractor has performed the installation. For alterations, the installation performed by TPQCP contractors may be approved at the enforcement agency's discretion, based upon a properly completed certificate of installation (NRCI-MCH-01) and certificate of acceptance (NRCA-MCH-04-A). If subsequent HERS compliance verification procedures determine that resampling, full testing, or corrective action is necessary for such conditionally approved dwellings in the group, the corrective work must be completed. If the Energy Code requires registration of the compliance documents, the certificates of installation and certificates of acceptance must be registered copies from a nonresidential data registry and a HERS provider data registry, respectively.

Refer to Reference Nonresidential Appendix NA1 for additional information about the Third Party Quality Control Program and for additional information about document registration.

2.3.6 For More Information

More details on field verification and diagnostic testing and the HERS Provider data registry are provided in the *2022 Reference Nonresidential Appendices* and *2022 Reference Joint Appendices*, as described below:

- Reference Nonresidential Appendix NA1 — Nonresidential HERS Verification, Testing, and Documentation Procedures
- Reference Nonresidential Appendix NA2 — Nonresidential Field Verification and Diagnostic Test Procedures
- Reference Joint Appendix JA7 — Data Registry Requirements

2.4 Roles and Responsibilities

Effective compliance and enforcement require coordination and communication among the architects, engineers, lighting and HVAC designers, permit applicant, contractors, plans examiner, and field inspector.[1] This manual recommends procedures to improve communication.

1 For small projects, an architect or engineer may not be involved, and the contractor may be the permit applicant.

The building design and construction industry, as well as enforcement agencies, are organized around these engineering disciplines:[2]

- The design of the electrical and lighting system of the building is typically the responsibility of the **lighting designer, electrical engineer, or electrical contractor**. This person is responsible for designing a system that meets the Energy Code, producing the building plans and specifications, and completing the compliance documents and worksheets.
- In larger enforcement agencies, an **electrical plans examiner** is responsible for reviewing the electrical plans, specifications, and compliance documents, and an **electrical field inspector** is responsible for verifying the correct installation of the systems in the field.
- The **mechanical plans examiner** is responsible for reviewing the mechanical plans, and a **mechanical field inspector** is responsible for verifying correct construction in the field.
- For the building envelope, the **architect** is typically responsible for designing the building and completing the documents.
- The **enforcement agency** is responsible for reviewing the design and documents, and the **enforcement agency field inspector** is responsible for verifying the construction in the field.

Unless the whole-building performance approach is used, the compliance and enforcement processes can be completed separately for each discipline. This enables each discipline to complete the work independently of others. For example, an applicant can use the prescriptive approach for the water heating and indoor lighting, then use the performance approach for all other building components. To simplify this process, compliance documents have been grouped by discipline.

2.4.1 Designer

5537 and 6737.1 of California Business and Professions Code

The designer is responsible for the overall building design. The designer is also responsible for specifying the building features that determine compliance with the Energy Code and other applicable building codes. Designers are required to provide a signature on the respective NRCCs to certify that the building has been designed to comply with the Energy Code.

The designer may be an architect, engineer, or other California-licensed professional and may personally prepare the NRCCs. This professional may delegate preparation of the energy analysis and certificate of compliance documents to an energy documentation author or energy consultant. If preparation of the building energy NRCC documentation is delegated, the designer must remain in charge of the

2 Small enforcement agencies may not have this type of specialization.

building design specifications, energy calculations, and all building feature information represented on the NRCC. The designer's signature on the NRCC affirms responsibility for the information submitted on the NRCC. When the designer is a licensed professional, the signature block on the NRCCs must include the designer's license number.

2.4.2 Documentation Author

§10-103(a)1

The person responsible for the design of the building may delegate the energy analysis and preparation of the NRCCs documentation to a building energy consultant or documentation author. Completed NRCCs documentation must be submitted to the enforcement agency during the building permit phase. The NRCCs demonstrate to the enforcement agency plans examiner that the building design complies with the Energy Code. Moreover, the building energy features information submitted on the NRCCs must be consistent with the building plans and specifications.

The documentation author is not subject to the same limitations and restrictions of the *Business and Professions Code* as the building designer because the documentation author is not responsible for specification of the building design features. The documentation author may provide the building designer with recommendations for building energy features that must be incorporated into the building design plans and specification documents submitted to the enforcement agency at plan check. The documentation author’s signature on the NRCCs certifies that the documentation they have prepared is accurate and complete but does not indicate their responsibility for the specification of the features that define the building design. The documentation author provides completed NRCC documents to the building designer, who must sign the NRCCs prior to submittal of the NRCCs to the enforcement agency at plan check.

2.4.3 Builder or General Contractor

The term *builder* refers to the general contractor responsible for construction. During construction, the builder or general contractor usually hires specialty subcontractors to provide specific services, such as installing insulation and designing and installing HVAC systems. The builder or general contractor must ensure that the certificate(s) of installation is submitted to the enforcement agency by the person(s) responsible for construction/installation of regulated features, materials, components, or manufactured devices. The builder or general contractor may sign the NRCIs (as the responsible person) on behalf of the specialty subcontractors they hire, but generally, preparation and signature responsibility reside with the specialty subcontractor who provided the installation services. The NRCIs identify the installed features, materials, components, or manufactured devices detailed in the building plans and the NRCCs. A copy of each NRCI is required to be posted at the building site for review by the enforcement agency in conjunction with requests for final inspection.

At final inspection, the builder or general contractor is required to leave all applicable completed and signed compliance documents for the building owner at occupancy in the building. Such information must, at a minimum, include information indicated on the following documents: NRCCs, NRCIs, NRCAs, and HERS verifications. These documents may be in paper or electronic format and must conform to the applicable requirements of §10-103(a).

2.4.4 Specialty Subcontractors

Specialty subcontractors provide the builder with services from specific building construction trades for installation of features such as wall and ceiling insulation, windows, HVAC systems or duct systems or both, water heating, and plumbing systems. These subcontractors may perform other trade-specific specialty services during building construction. The builder has ultimate responsibility for all aspects of building construction and has the authority to complete and sign/certify all sections of the required NRCIs documents. However, the licensed specialty subcontractor should be expected to complete and sign/certify all applicable NRCIs that document completion of the installation work they have performed for the builder. The subcontractor's responsibility for NRCI documentation includes providing a signed and registered copy of all applicable NRCIs to the builder and posting the documents at the building site for review by the enforcement agency.

2.4.5 Enforcement Agency

§10-103

The enforcement agency is the local agency with responsibility and authority to issue building permits and verify compliance with applicable codes and standards. The enforcement agency performs several key roles in the compliance and enforcement process.

A. Plan check: The enforcement agency performs the plan review of the NRCCs and the building plans and specifications. During plan review, the NRCCs are compared to the plans and specifications for the building design to confirm that the building is specified consistently in all the submitted documents. If the specifications for the building design features shown on the NRCCs do not conform to the specifications shown on the designer's submitted plans and specifications for the building, the submitted documents must be revised to make the design specification consistent in all documents. Thus, if the features on the NRCCs are consistent with the features given in the plans and specifications for the building design and indicates that the building complies, then the enforcement agency may issue a building permit.

B. Construction inspection: During building construction, the enforcement agency should make several visits to the construction site to verify that the building is being constructed in accordance with the approved plans and specifications and energy compliance documentation. As part of this process, at each site visit, the enforcement agency should review any applicable NRCIs that have been posted or made available with the building permit(s). The enforcement agency should confirm that:

- The energy efficiency features installed in the building are consistent with the requirements given in the plans and specifications for the building approved during plan review.
- The installed features are described accurately on the NRCIs.
- All applicable sections of the NRCIs have been signed by the responsible licensed person(s).

The enforcement agency does not approve a building until it has received all applicable NRCIs.

C. **Final approval:** The enforcement agency may approve the building at the final inspection phase if the enforcement agency field inspector determines that:

- the building conforms to the requirements of the building plans and specifications,
- the NRCCs are approved by the enforcement agency at plan review,
- and the building meets the requirements of all other applicable codes and standards.

For buildings that have used an energy efficiency compliance feature that requires an NRCI, the enforcement agency shall not approve the building until it has received an NRCI that meets the requirements of §10-103(a) and has been completed and signed by the builder or subcontractor for each compliance feature. The builder must ultimately take responsibility to ensure that all required energy compliance documentation has been completed properly and posted at the job site or submitted to the enforcement agency in conjunction with any of the enforcement agency's required inspections. However, the enforcement agency, in accordance with §10-103(d), must examine all required copies of NRCIs, NRCAs, and HERS verification made available for the required inspections. It must confirm that these documents have been properly prepared and are consistent with the plans, specifications, and the NRCCs approved by the enforcement agency for the building at plan review.

D. **Corroboration of information provided for the owner/occupant:** At final inspection, the enforcement agency shall require the builder to leave energy compliance, operating, maintenance, and ventilation information documentation in the building (for the building owner at occupancy) as specified by §10-103(b).

Compliance documents for the building shall, at a minimum, include:

- NRCCs.

- NRCIs.
- NRCAs.
- HERS verification.

These documents are copies of the documentation submitted to or approved by the enforcement agency, and the copies must conform to the applicable requirements of §10-103(a).

Operating information includes instructions on how to operate or maintain the energy features, materials, components, and mechanical devices of the building correctly and efficiently. Such information shall be contained in a folder or manual that provides all information specified in §10-103(b). This operating information is in paper or electronic format. For dwelling units, buildings, or tenant spaces that are not individually owned and operated, or are centrally operated, this information is provided to the person(s) responsible for operating the feature, material, component, or mechanical device installed in the building.

Maintenance information is provided for all features, materials, components, and manufactured devices that require routine maintenance for efficient operation. Required routine maintenance actions are clearly stated and incorporated on a readily accessible label. The label may be limited to identifying, by title or publication number or both, the operation and maintenance manual for that particular model and type of feature, material, component, or manufactured device. For dwelling units, buildings, or tenant spaces that are not individually owned and operated, or are centrally operated, such information is provided to the person(s) responsible for maintaining the feature, material, component, or mechanical device installed in the building. This maintenance information shall be in paper or electronic format.

Ventilation information includes a description of the quantities of outdoor air that the ventilation system(s) are designed to provide to the conditioned space of the building, and instructions for proper operation and maintenance of the ventilation system. For buildings or tenant spaces that are not individually owned and operated, or are centrally operated, such information is provided to the person(s) responsible for operating and maintaining the feature, material, component, or mechanical ventilation device installed in the building. This information is in paper or electronic format.

2.4.6 Permit Applicant

The permit applicant is responsible for:

1. Providing information on the plans or specifications or both to enable the enforcement agency to verify that the building complies with the Energy Code. It is important to provide all necessary detailed information on the plans and specifications. The plans are the official record of the permit. The design professional is responsible for certifying that the plans and specifications are

consistent with the energy features listed on the NRCCs, and that the design complies with the standards.

2. Performing the necessary calculations to show that the building or system meets the Energy Code. These calculations may be documented on the drawing or on the worksheets provided in the manual and supported, when necessary, with data from national rating organizations or product or equipment manufacturers or both.
3. Completing the NRCC summary document. The NRCC is a listing of each of the major requirements of the Energy Code that applies to the project. The summary document includes information from the worksheets and references to the plans where the plans examiner can verify that the building or system meets the Energy Code.

2.4.7 Plans Examiner

The plans examiner is responsible for:

1. Reviewing the plans and supporting material to verify that they contain the necessary information for a plan review.
2. Checking the calculations and data contained on the worksheets.
3. Indicating by checking a box on the summary documents that the compliance documentation is acceptable.
4. Making notes for the field inspector about which items require special attention.

2.4.8 Field Inspector

The field inspector is responsible for:

1. Verifying that the building or system is constructed according to the plans.
2. Checking off appropriate items on the summary document at each relevant inspection.
3. Verifying that all the required compliance documentation (NRCIs, NRCAs, and HERS Verifications) is completed, dated, signed, and registered (when applicable).

The NRCCs may be used by the building permit applicant, the plans examiner, and the field inspector. This way, the permit application can call the plans examiner's attention to the relevant drawing sheets and other information, and the plans examiner can call the field inspector's attention to items that may require special attention in the field. The compliance documents and worksheets encourage communications and coordination within each discipline.

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3 Building Envelope

3.1 Chapter Overview

This chapter covers the requirements for efficiency features used for the building envelope of nonresidential, hotel and motel occupancy building types. Building energy use is affected by heating and cooling loads.

- **Heating loads** are affected by infiltration and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows, and doors.
- **Cooling loads** are dominated by solar gains through windows and skylights, internal gains due to lighting, plug loads, and occupant use, and from additional ventilation loads needed for indoor air quality.

3.1.1 What's New for 2022

The *2022 Building Energy Efficiency Standards* (Energy Code) include several important changes to the building envelope component requirements as described below:

- Steep-sloped cool roof prescriptive requirements were increased from a solar reflectance of 0.20 and thermal emittance of 0.75 to solar reflectance of 0.25 and thermal emittance of 0.85 in Climate Zones 2 and 4 through 16.
- Added a new prescriptive requirement for continuous above roof deck insulation for roof alterations. For roof replacements the requirement is R-23 in Climate Zones 1 through 5 and 9 through 16, and R-17 in Climate Zones 6 through 8. For roof recovers, the requirement calls for a minimum R-10 insulation be added or to meet the insulation requirements for roof replacements, whichever is less.
- Prescriptive fenestration requirements (U-factor and RSHGC) now vary by climate zone, but visible transmittance (VT) remains the same. For fixed windows, the U-factor and RSHGC requirements were reduced in Climate Zones 9 and 11 through 15. For curtain wall and storefront windows, the U-factor and RSHGC requirements were reduced in Climate Zones 1 and 7.
- Revised the RSHGC equation (Equation 140.3-A) to provide credit for exterior horizontal slats, in addition to overhangs.
- Reduced the prescriptive U-factor requirement for metal framed walls equivalent to an additional R-2 continuous insulation.

3.2 Opaque Envelope Assembly

This section addresses the requirements for thermal control of the opaque portion of the building shell or envelope. Fenestration, windows, skylights, and glazed doors are addressed in Section 3.3.

3.2.1 Opaque Envelope Definitions

Opaque elements of the building envelope contribute significantly to the energy efficiency of the building and its design intent. Components of the building shell include the walls, floor, the roof or ceiling, doors, and fenestration. Definitions for fenestration are addressed in Section 3.3.

Envelope and other building components definitions are listed in §100.1(b) of the Energy Code and the Reference Joint Appendices JA1.

A. **Conditioned space** is either directly conditioned or indirectly conditioned. (See §100.1[b] for full definition.) Indirectly conditioned space is influenced more by directly adjacent conditioned space than it is by ambient (outdoor) conditions.

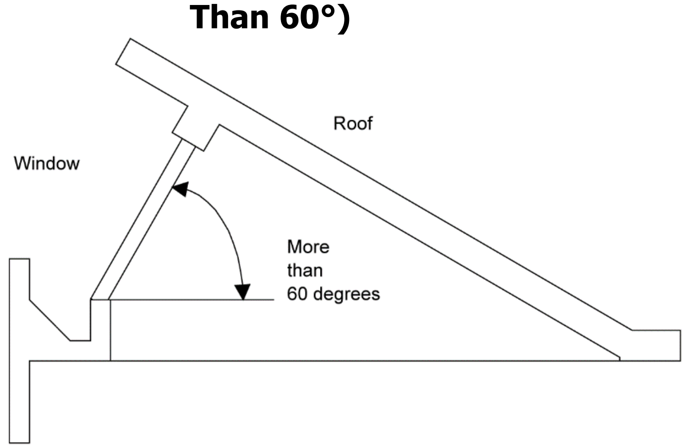
B. **Unconditioned space** is an enclosed space within a building that is not directly conditioned or indirectly conditioned.

C. **Air Leakage.** Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. It is a major component of heating and cooling loads. Infiltration can occur through holes and cracks in the building envelope. Major Sources of infiltration are often where assemblies meet, as well as around doors and fenestration framing areas and roof penetrations.

D. **Ventilation** is the *intentional* replacement of conditioned air with unconditioned air through open windows and skylights or mechanical systems. Mechanical systems are the preferred ventilation method it can be designed to condition or filter unconditioned air.

E. **Sloping surfaces** are considered either a wall or a roof, depending on the slope. (See Figure 3-1.) If the surface has a slope of less than 60 degrees from horizontal, it is considered a roof; a slope of 60 degrees or more is a wall. This definition extends to fenestration products, including windows in walls and any skylights in roofs.

Figure 3-1: Slope of a Wall or Window (Roof or Skylight Slope Is Less Than 60°)



Source: California Energy Commission

F. **Exterior partition or wall** is an envelope component (roof, wall, floor, window, etc.) that separates conditioned space from ambient (outdoor) conditions. An exterior wall is considered separate from a demising wall or demising partition and has more stringent thermal requirements.

G. **Demising partition or wall** is an envelope component that separates conditioned space from an enclosed unconditioned space.

H. **Exterior floor** is a horizontal exterior element under conditioned space and above ambient (outdoor) conditions.

I. **Soffit** is a horizontal demising element, under conditioned space and above an unconditioned space.

J. **Attic** is a space below an uninsulated roof that has insulation on the attic floor and is an unconditioned space because there is less thermal resistance to the outside than across the insulated ceiling to the conditioned space below.

K. **Plenum** is an air compartment or chamber, including uninhabited crawl space, areas above a ceiling or below a floor, including air spaces below raised floors of computer/data processing centers, or attic spaces, to which one or more ducts are connected and which forms part of either the supply-air, return-air, or exhaust air system, other than the occupied space being conditioned.

L. **Exterior roof** has a slope less than 60 degrees from horizontal and has conditioned or indirectly conditioned space below with ambient (outdoor) conditions space above.

M. **Ceiling** is a demising element that has a slope less than 60 degrees from horizontal and has conditioned space below with unconditioned space above.

N. **Roof deck** is the surface of an exterior roof that is directly above the roof rafter and below exterior roofing materials.

O. **Roofing products (cool roofs).** Roofing products with a high solar reflectance and thermal emittance are referred to as "*cool roofs*." These roofing types absorb less solar heat and give off more heat to the surroundings than traditional roofing materials. These roofs are cooler and thus help reduce air conditioning loads by reflecting and emitting energy from the sun.

P. **Solar reflectance** is the fraction of solar energy that is reflected by the roof surface.

Q. **Thermal emittance** is the fraction of thermal energy that is emitted from the roof surface.

R. **Low-sloped roof** is a surface with a pitch less than 2:12 (less than 9.5 degrees from the horizon).

S. **Steep-sloped roof** is a surface with a pitch greater than or equal to 2:12 (9.5 degrees from the horizontal or more).

T. **Air barrier** is a combination of interconnected materials and assemblies joined and sealed together to provide a continuous barrier to air leakage through the building envelope, which separates conditioned from unconditioned space, or adjoining conditioned spaces of different occupancies or uses.

U. **Vapor retarder or barrier** is a special covering over framing and insulation or covering the ground of a crawl space that protects the assembly components from possible damage due to moisture condensation.

3.2.2 Thermal Properties of Opaque Envelope Components

Opaque envelope assemblies are made up of a variety of components, such as wood or metal framing, masonry or concrete, insulation, and other membranes for moisture and/or fire protection and may have a variety of interior and exterior sheathings even before the final exterior façade is placed. Correctly calculating assembly U-factors is critical to the selection of equipment to meet the heating and cooling loads of the building. Performance compliance software automatically calculates the thermal effects of component layers making up the envelope assembly, but software programs may use different user input hierarchies. The Reference Joint Appendices JA4, "U-factor, C-factor, and Thermal Mass Data," provide detailed thermal data for many wall, roof/ceiling, and floor assemblies. However, JA4 cannot cover every possible combination of materials and thickness that might be used in a building. For this reason, the Energy Commission has incorporated into the public domain software CBECC-COM, a program for calculating material properties of typical envelope assemblies which are not found in JA4.

Key terms of assembly thermal performance are:

A. **Btu** (British thermal unit): The amount of heat required to raise the temperature of 1 pound of water 1°F.

B. **Btuh or Btu/hr** (British thermal unit per hour): The rate of heat flow during an hour. The term is used to rate the output of heating or cooling equipment or the load that equipment must be capable of handling, that is, the capacity needed for satisfactory operation under stated conditions.

C. **R or R-value** (thermal resistance): The ability of a material or combination of materials to retard heat flow. As the resistance increases, the heat flow is reduced. The higher the **"R-value"**, the greater the insulating value. R-value is the reciprocal of the conductance, **"C-value."**

$$\text{R-value} = \text{hr} \times \text{ft}^2 \times {}^{o}\text{F/Btu}$$

$$R = \text{inches of thickness}/k$$

D. **U or U-factor** (thermal transmittance or coefficient of heat transmission): The rate of heat transfer across an envelope assembly per degree of temperature difference on either side of the envelope component. U-factor is a function of the materials and related thickness. U-factor includes air film resistances on inside and outside surfaces. U-factor applies to heat flow through an assembly or system, whereas "**C**" has the same dimensional units and applies to individual materials. The lower the "**U**" the higher the insulating value.

U-factor = Btu/(hr x ft^2 x °F)

E. **k or k-value** (thermal conductivity): The property of a material to conduct heat in the number of Btu that pass through a homogeneous material 1 inch thick and 1 square foot in area in an hour with a temperature difference of 1°F between the two surfaces. The lower the "**k"** the greater the insulating value.

k = Btu x in/(hr x ft^2 x °F)

F. **C or C-value** (thermal conductance): The number of Btu that pass through a material of any thickness and 1 square foot in area in an hour with a temperature difference of 1°F between the two surfaces. The time rate of heat flow through unit area of a body induced by a unit temperature difference between the body surfaces. The C-value does not include the air film resistances on each side of the assembly. The term is applied usually to homogeneous materials but may be used with heterogeneous materials such as concrete block. If **"k"** is known, the **"C"** can be determined by dividing **"k"** by inches of thickness. The lower the "C", the greater the insulating value.

C = Btu/(hr. x ft^2 x °F) or C = k/inches of thickness

G. **HC** (heat capacity – thermal mass): The ability to store heat in units of Btu/ft^2 and is a property of specific heat, density, and thickness of a given envelope component. High thermal mass building components, such as tilt-up concrete walls, can store heat and release stored heat later in the day or night. The thermal storage capability of high mass walls, floors, and roof/ceilings can slow heat transfer and shift heating and cooling energy affecting building loads throughout a 24-hour period, depending on the design, location, and occupancy use of a building.

3.2.3 General Envelope Requirements

This section contains mandatory requirements that are not specific to one envelope component.

3.2.3.1 Mandatory Requirements

A. Certification of Insulation Materials

§110.8(a)

Manufacturers must certify that insulating materials comply with the *California Quality Standards for Insulating Materials*, which became effective January 1,

1982. It ensures that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health, and safety standards.

Builders may not install insulating materials, unless the product has been certified by the Department of Consumer Affairs, Bureau of Electronic and Appliance Repair, Home Furnishing and Thermal Insulation. Builders and enforcement agencies shall use the Department of Consumer Affairs *Directory of Certified Insulation Materials* to verify certification of the insulating material. If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Bureau of Household Goods and Services, at (916) 999-2041 or by email: HomeProducts@dca.ca.gov.

B. Urea Formaldehyde Foam Insulation

§110.8(b)

The mandatory requirements restrict the use of urea formaldehyde foam insulation. The restrictions are intended to limit human exposure to formaldehyde, which is a volatile organic chemical known to be harmful to humans.

If foam insulation is used that has urea formaldehyde, it must be installed on the exterior side of the wall (not in the cavity of framed walls), and a continuous barrier must be placed in the wall construction to isolate the insulation from the interior of the space. The barrier must be 4-mil (0.1 mm) thick, polyethylene or equivalent.

C. Flame Spread Index and Smoke Development Index of Insulation

§110.8(c)

The *California Quality Standards for Insulating Materials* requires that all exposed installations of faced mineral fiber and mineral aggregate insulations use fire-retardant facings that have been tested and certified not to exceed a flame spread index of 25 and a smoke development index of 450. Insulation facings that do not touch a ceiling, wall, floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing are considered exposed applications. Flame spread index and smoke density index are shown on the insulation or packaging material or may be obtained from the manufacturer.

D. Infiltration and Air Leakage

§110.7

All joints and other openings in the building envelope that are potential sources of air leakage must be caulked, gasketed, weather stripped, or otherwise sealed to limit air leakage. This applies to roof penetrations and to penetrations for pipes and conduits, ducts, vents, and other openings in the building envelope. Particular attention should be paid to the junctures where assemblies meet, and all gaps between wall panels, around doors, and other construction joints. Ceiling joints, lighting fixtures, and rough openings for doors and windows should all be considered potential sources of unnecessary energy loss due to infiltration. No special construction requirements are necessary for suspended (T-bar) ceilings, provided they meet the requirements of §110.7.

E. Mandatory Insulation Requirements (Newly Constructed Buildings)

§120.7

Newly constructed nonresidential and hotels/motel buildings must meet mandatory insulation requirements for opaque portions of the building that separate conditioned spaces from unconditioned spaces or ambient air.

See the sections on roof, walls, doors, and floors

An exception is specified that exempts buildings designed as data centers with high, constant server loads from the mandatory minimum requirements. To qualify for this exception, the building should have a design computer room process load of 750 kW or greater.

3.2.4 Prescriptive Requirements

A. Air Barrier

§140.3(a)9, TABLE 140.3-B

The 2022 Energy Code requires that the air barrier is clearly detailed on construction documents and that acceptable air barrier materials are used. Verification is carried out by blower door testing – this measurement procedure is described in Nonresidential Appendix NA5.

Construction documents shall include details, notes, or specifications to clearly identify air barrier boundaries, interconnections, penetrations, and associated square foot calculations for all sides of the air barrier.

Table 140.3-B of the Energy Code specifies material requirements for air barriers in nonresidential buildings. Air barrier requirements apply to nonresidential buildings, but not relocatable public school buildings, and cannot be traded off in the performance approach. These requirements reduce the overall building air leakage rate. The reduction in air leakage can be met with a continuous air barrier that seals all joints and openings in the building envelope and is composed of one of the following:

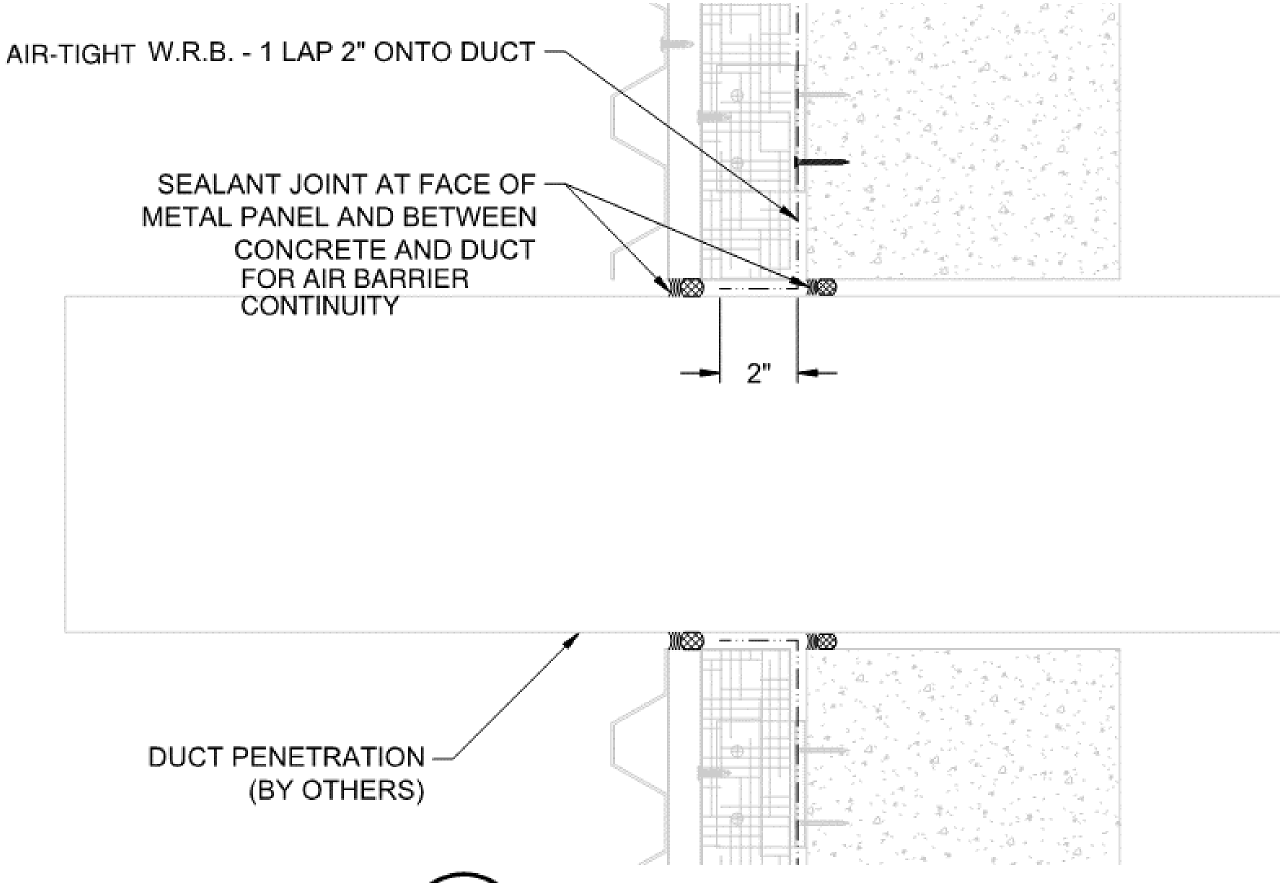
1. Materials having a maximum air permeance of 0.004 cfm/ft² (see Table 3-1).
2. Assemblies of materials and components having an average air leakage not exceeding 0.04 cfm/ft².
3. An entire building having an air leakage rate not exceeding 0.40 cfm/ft2.

The air leakage requirements stipulated in §140.3 must be met, either by demonstrating that component air leakage of 0.04 cfm/ft2 or the whole-building air leakage of 0.4 cfm/ft² is not exceeded.

Table 3-1: Materials Deemed to Comply as Air Barrier

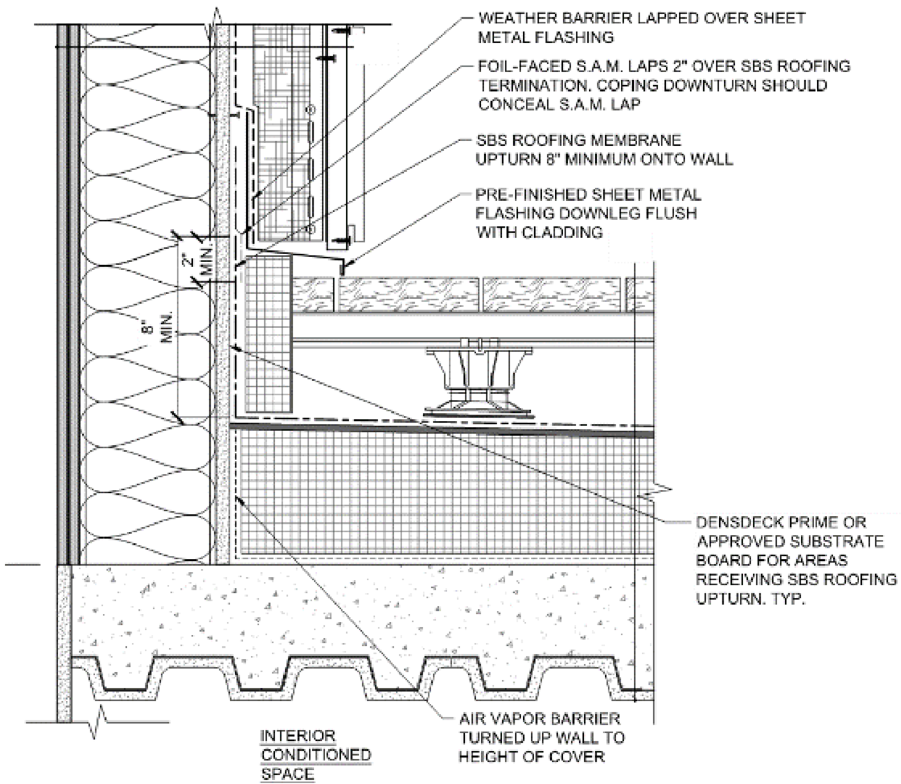
MATERIALS AND THICKNESS
Plywood – min. 3/8 inches thickness
Oriented strand board – min. 3/8 inches thickness
Extruded polystyrene insulation board – min. ½ inches thickness
Foil-back polyisocyanurate insulation board – min. ½ inches thickness
Closed- cell spray foam with a minimum density of 2.0 pcf and a min. 1½2.0 inches thickness
Open cell spray foam with a density no less than 0.4 pcf and no greater than 1.5 pcf, and a min. 5½ inches thickness
Exterior or interior gypsum board min. ½ inches thickness
Cement board – min. ½ inches thickness
Built-up roofing membrane
Modified bituminous roof membrane
Fully adhered single-ply roof membrane
A Portland cement or Portland sand parge, or a gypsum plaster, each with min. 5/8 inches thickness
Cast-in-place concrete, or precast concrete
Fully grouted concrete block masonry
Sheet steel or sheet aluminum

Figure 3-2: Examples of Reflecting Building Air Barrier Diagram to Prevent Conduction



Source: California Statewide CASE Team

Figure 3-3 Sample Detail Indicating Strategy of Maintaining Air Barrier Continuity Across Specific Detail – a Duct Penetration of a Concrete Wall



Sample of Pre-Test Coordination Steps *(Performed by Testing Agency)*

a. The testing agency should have experience performing blower door tests of similar scope and complexity. A minimum of two years of experience is strongly recommended.
b. Confirm envelope air barrier boundary and total area from design team.
c. Calculate number of fans required to perform air leakage test in accordance with ASTM E3158. Separate air barrier zones are required to have independent fan setup unless it is confirmed that demising walls to adjacent air barrier boundaries will not be constructed at the time of test. (see Figure 3-3.1)
d. Identify on floor plan locations of fan stations, as well as locations of external and internal reference points. Identify doorways that are required to be open to allow for air flow to communicate between zones.
e. Work with contractor to coordinate pre-test meeting with electrical, mechanical (or controls), and elevator subcontractors to review electrical needs for testing equipment and shutdown/sealing plan for mechanical systems and ductwork. Confirm required subcontractors that will be required on site to assist with execution on test day.

f. A pretest walk-through to monitor the preparation of the building (sealing of intentional openings, closure of operable envelope components, opening of doorways for air flow) is recommended.
g. Provide contractor with schedule of test day so that contractor can coordinate personnel access in/out of building during designated test times.

Figure 3-3.1: Sample Fan Calculation

A) Total building envelope area (Provided by Architect): 120,000 square feet

B) Allowable air leakage rate at 75 pascals: 0.4 CFM/square foot

C) Total allowable air leakage at 75 pascals (A X B) = 48,000 CFM

D) Maximum fan flow: 7500 CFM/fan

E) Total number of fans required (C/D) = 6.4 fans.

F) Number of additional independent air barrier zones (retail spaces, mechanical rooms,etc) = 2 fans

G) Total number of fans required (E + F, round up) = 9 fans

Note – all items represented in red are to be confirmed with project design team and fan manufacturer. This example is not related to the images in the rest of the appendix

Source: California Statewide CASE Team

Figure 3-3.2: Sample Diagram of Air Barrier Zones Identified, With Fan Stations and Doorway Openings (Opened/Closed) Indicated on Plan. Provided by testing agency

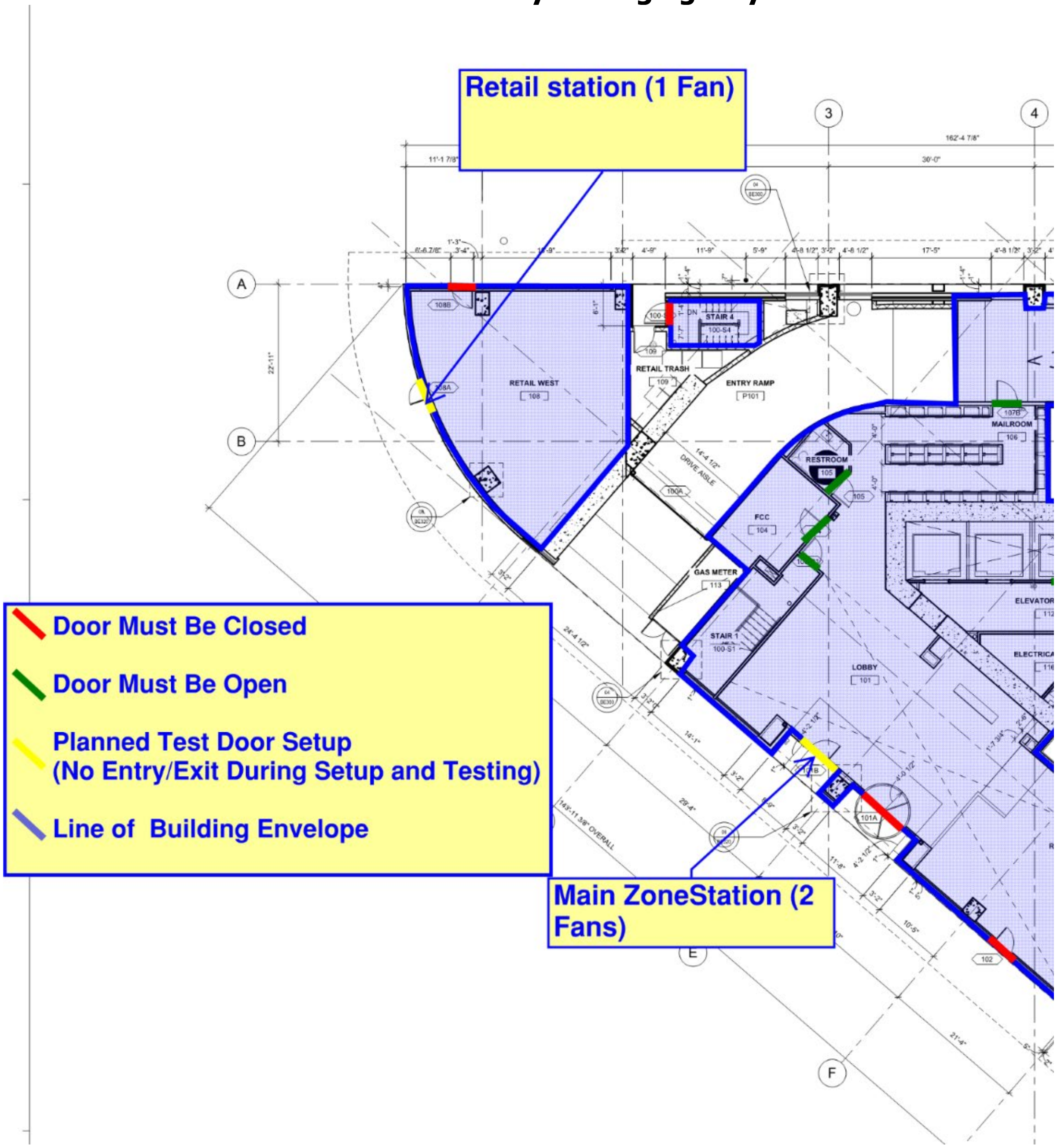


Figure 3-3.3: Sample Test Schedule Provided by Testing Agency to Contractor

Test Day Approximate Schedule

8:00am to 2:00pm	Test Agency arrives on site and begins equipment setup. Team leader meets with General Contractor and performs final assessment of the building and temporary sealing measures. Once setup begins, access to doors selected for fan setup is restricted. GC: Final temporary air sealing of building/HVAC shutdown. *All temporary sealing work must be complete by 11:00 AM on the test day.*
2:00pm to 3:30pm	Preliminary tests – (if applicable) workers can be in the building but Test Agency requires that all exterior doors and windows remain closed and that any ingress/egress be coordinated with Test Agency.
3:30pm to 4:00pm	Clear building of all workers not involved in testing.
4:00pm to 5:00pm	Full performance verification testing– no access to building by anyone not involved in testing.
5:00pm to 7:00pm	Tear down and pack up test equipment.

The testing agency shall perform a pre-test inspection in accordance with Nonresidential Appendix NA5.3 in coordination with the general contractor (GC) and direct the GC to complete the pre-test setup in accordance with Nonresidential Appendix NA5.3.

Test Execution *(Performed by Testing Agency)*

a. Deliver equipment in accordance with test plan.

b. Perform site walk with general contractor (GC) to perform final assessment of building and temporary sealing measures (identified during pretest meetings and in GC setup guidelines). Identify all areas of incomplete or damaged envelope areas that could potentially affect the result of the air leakage test.

c. Confirm that access through fan station setup openings is restricted for other trades. Identify pathways of which wires and tubes will be run such that the GC can assess and mitigate safety hazards and damages to equipment accordingly.

d. Perform setup of fan stations:

- Ensure that doorway(s) the blower door panel is set within is sealed around the perimeter to reduce the amount of air loss through the opening.

- Confirm that all stations are setup with fans in the correct direction of airflow (inward for pressurization, outward for depressurization).
- Reference tubes used to measure pressure differential across the building envelope should be placed out of paths of significant airflow.

e. Coordinate a temporary shutdown with GC of access to the building to perform preliminary test on building. During this preliminary test, fans should be ramped up to attempt to achieve target pressure for the air leakage test. Based off of the pressure obtained, the testing agency should be able to assess if preparation work of the building needs to be further reviewed.

1. If the schedule allows, coordinate a walkthrough with the GC with the building under pressure to determine if any intentional openings were not properly sealed or secured.
2. If infrared scanning equipment is available, perform a scan of building to assist in identifying any air leakage out of unintentional openings and intentional openings that were not properly sealed or secured.

f. Following the preliminary test, testing agency should also assess if adjustments to station setups are required to improve pressure distribution and flow readings. Changes to the test setup should be documented for the record.

g. Once the preliminary test has been completed and any repairs to the preparation work have been completed, testing agency to complete the test in accordance with Nonresidential Appendix NA5.5 of the Energy Standards and ASTM E3158. Upon collection of data points in accordance with ASTM E3158, the testing agency should be able to determine an approximate air leakage per envelope area based off of building inputs (envelope area, temperature differential, wind speeds height above elevation, etc.). The testing agency should then confirm this value using the fan manufacturer's software with the GC to determine if the building passed the test.

h. If the building failed the test, perform reviews using methods of Nonresidential Appendix NA5.7 and ASTM E1186.

3.2.5 Roofing Products and Insulation

3.2.5.1 Mandatory Requirements

A. Roof/Ceiling Insulation

§120.7(a)

Metal Building: Weighted average U-factor of U-0.098 (R-19 screw down roof, no thermal blocks).

Wood-Framed and Others: Weighted average U-factor of U-0.075 (2x4 rafter, R-19 insulation).

B. Insulation Placement on Roof/Ceilings

§120.7(a)3

Insulation installed on top of suspended (T-bar) ceilings with removable ceiling panels may not be used to comply with the Energy Code unless the installation meets the criteria described in the *Exception* to §120.7(a)3 below. Insulation may be installed in this location for other purposes such as for sound control, but it will have no value in terms of meeting roof/ceiling insulation requirements of the Energy Code.

Acceptable insulation installations include placing the insulation in direct contact with a continuous roof or ceiling that is sealed to limit infiltration and exfiltration as specified in §110.7, including, but not limited to, placing insulation either above or below the roof deck or on top of a drywall ceiling.

When insulation is installed at the roof in nonresidential buildings, the space between the ceiling and the roof is considered either directly or indirectly conditioned space. Therefore, this space must not include fixed vents or openings to the outdoors or to unconditioned spaces. This space is not considered an attic for complying with California Building Code (CBC) attic ventilation requirements. Vents that do not penetrate the roof deck and that are designed for wind resistance for roof membranes are acceptable.

Exception to §120.7(a)3: When there are conditioned spaces with a combined floor area no greater than 2,000 square feet in an otherwise unconditioned building, and when the average height of the space between the ceiling and the roof over these spaces is greater than 12 feet, insulation placed in direct contact with a suspended ceiling with removable ceiling panels shall be an acceptable method of reducing heat loss from a conditioned space and shall be accounted for in heat loss calculations.

C. Wet Insulation Systems

§110.8(h)

Wet insulation systems are roofing systems where the insulation is installed above the roof's waterproof membrane. Water can penetrate this insulation material and affect the energy performance of the roofing assembly in wet and cool climates. In climate zones 1 and 16, the insulating R-value of continuous insulation materials installed above the waterproof membrane of the roof must be multiplied by 0.8 before choosing the table column in Reference Joint Appendix JA4 for determining assembly U-factor. See the footnotes in JA4 for Tables 4.2.1 through 4.2.7.

D. Roofing Products: Aged Solar Reflectance (SR) and Thermal Emittance (TE)

§10-113, §110.8(i)

In general, light-colored, high-reflectance surfaces reflect solar energy (visible light, invisible infrared, and ultraviolet radiation) and stay cooler than darker surfaces that absorb the sun's energy and become heated. The Energy Code prescribes cool roof radiative properties for low-sloped and steep-sloped roofs. Low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is higher in the sky.

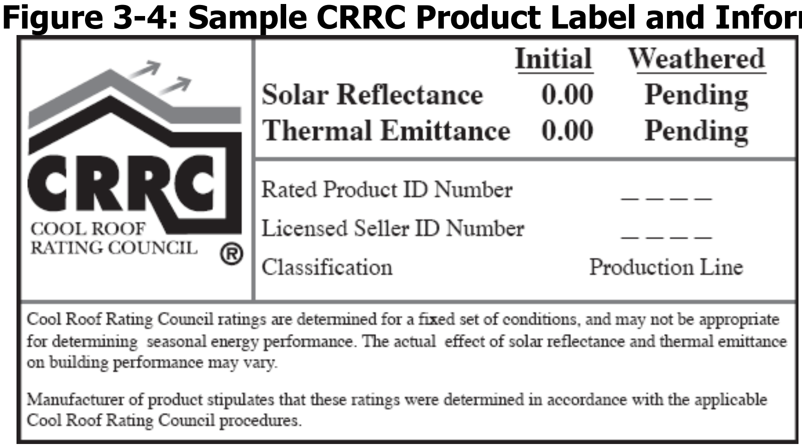
Roofing products must be tested and labeled by the Cool Roof Rating Council (CRRC), and liquid-applied products must meet minimum standards for performance and durability per §110.8(i)4. When installing cool roofs, the aged solar reflectance and thermal emittance of the roofing product must be tested and certified according to CRRC procedures. The aged solar reflectance and thermal emittance properties are rated and listed by the Cool Roof Rating Council at www.coolroofs.org. When a CRRC rating is not obtained for the roofing products, the Energy Code default values for solar reflectance and thermal emittance must be used.

1. Rating and Labeling

§10-113

When a cool roof is installed to meet the prescriptive requirement or when it is used for compliance credit, the products must be tested and labeled by the CRRC as specified in §10-113. The CRRC is the supervisory entity responsible for certifying cool roof products. The CRRC test procedure is documented in CRRC-1, the *CRRC Product Rating Program Manual.* This test procedure includes tests for both solar reflectance and thermal emittance. See Figure 3-4 for an example of an approved CRRC product label.

Figure 3-4: Sample CRRC Product Label and Information



Source: Cool Roof Rating Council

2. Solar Reflectance, Thermal Emittance, and Solar Reflectance Index (SRI)

§110.8(i)1-3

Both solar reflectance and thermal emittance are measured from 0 to 1; the higher the value, the "cooler" the roof. There are numerous roofing materials in a wide range of colors that have adequate cool roof properties. Excess heat can increase the air-conditioning load of a building, resulting in increased air-conditioning energy needed for maintaining occupant comfort. High-emitting roof surfaces reject absorbed heat quickly (upward and out of the building) than roof surfaces with low-emitting properties.

Solar Reflectance (SR). There are three measurements of solar reflectance:

1. Initial solar reflectance
2. Three-year aged solar reflectance
3. Accelerated aged solar reflectance

All requirements of the Energy Code are based on the three-year aged solar reflectance. If the aged value for the reflectance is not available in the CRRC's Rated Product Directory, then the aged value shall be derived from the CRRC initial value or an accelerated testing process. Until the appropriate age-rated value for the reflectance is posted in the directory, or a new method of testing is used to find the accelerated solar reflectance, the equation below can be used to calculate the aged rated solar reflectance.

$$\text{Aged Reflectance}_{calculated} = (0.2 + \beta[\rho_{initial} - 0.2])$$

Where,

$\rho_{initial}$ = Initial reflectance listed in the CRRC Rated Product Directory

β= 0.65 for field-applied coating, or 0.70 for not a field-applied coating

Thermal Emittance. The Energy Code does not distinguish between initial and aged thermal emittance, meaning that either value can be used to demonstrate compliance with the Energy Code.

Default Values. If a manufacturer fails to obtain CRRC certificate for its roofing products, the following default aged solar reflectance and thermal emittance values must be used for compliance:

a. For asphalt shingles, 0.08/0.75.

b. For all other roofing products, 0.10/0.75.

Solar Reflectance Index (SRI). The temperature of a surface depends on the solar radiation incidence, surface reflectance, and emittance. The SRI measures the relative steady-state surface temperature of a surface with respect to standard white (SRI=100) and standard black (SRI=0) under the standard solar and ambient condition. A calculator has been produced that calculates the SRI by designating the solar reflectance and thermal emittance of the desired roofing material. The calculator can be found at http://www.energy.ca.gov/title24/2022standards. To calculate the SRI, either the initial or the three-year aged solar reflectance value of the roofing product may be used. By using the SRI calculator, a cool roof may comply with a lower emittance, as long as the aged solar reflectance is higher and vice versa.

3. Field-Applied Liquid Coatings

§110.8(i)4, Table 110.8-C

There are several liquid products, including elastomeric coatings and white acrylic coatings that qualify for field-applied liquid coatings. The Energy Code specifies minimum performance and durability requirements for field-applied liquid coatings in Table 110.8-C depending on the type of coating. These requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering.

4. Aluminum-Pigmented Asphalt Roof Coatings

Aluminum-pigmented coatings are silver-colored coatings that are commonly applied to modified bitumen and other roofing products. The coating has aluminum pigments that float to the surface of the coating and provides a shiny, surface. Because of the shiny surface and the physical properties of aluminum, these coatings have a thermal emittance below 0.75, which is the minimum rating for prescriptive compliance. The performance approach is typically used to achieve compliance with these coatings.

This class of field-applied liquid coatings shall be applied across the entire surface of the roof and meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied. Also, the aluminum-pigmented asphalt roof coatings shall be manufactured in accordance with ASTM D2824.[1] Standard specification is also required for aluminum-pigmented asphalt roof coatings, nonfibered, asbestos-fibered, and fibered without asbestos that are suitable for applying to roofing or masonry surfaces by brush or spray. Use ASTM D6848, Standard Specification

1 A. This specification covers asphalt-based, aluminum roof coatings suitable for application to roofing or masonry surfaces by brush or spray.
B. The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.
C. The following precautionary caveat pertains only to the test method portion, Section 8, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

for Aluminum Pigmented Emulsified Asphalt used as a Protective Coating for Roofing, installed in accordance with ASTM D3805,[2] Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.

a. Cement-Based Roof Coatings

This class of coatings consists of a layer of cement and has been used for several years in California's Central Valley and other regions. These coatings may be applied to almost any type of roofing product. Cement-based coatings shall be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the manufacturer. Also, cement-based coatings shall be manufactured to contain no less than 20 percent Portland cement and meet the requirements of ASTM D822,[3] ASTM C1583, and ASTM D5870.

b. Other Field-Applied Liquid Coatings

Other field-applied liquid coatings include elastomeric and acrylic-based coatings. These coatings must be applied across the entire surface of the roof to meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied. The field-applied liquid coatings must be tested to meet performance and durability requirements as specified in Table 110.8-C of the Energy Code or the minimum performance requirements of ASTM C836, D3468, D6083, or D6694, whichever are appropriate to the coating material.

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2 A. This guide covers the application methods for Specification D 2824 Aluminum-Pigmented Asphalt Roof Coatings, Non-Fibered (Type I), Asbestos Fibered (Type II), and Fibered without Asbestos (Type III), for application on asphalt built-up roof membranes, modified bitumen roof membranes, bituminous base flashings, concrete surfaces, metal surfaces, emulsion coatings, and solvent-based coatings. This guide does not apply to the selection of a specific aluminum-pigmented asphalt roof coating type for use on specific projects.
B. The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.
C. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific precautionary statements are given in Section 4.

3 A. This guide is intended for the evaluation of clear and pigmented coatings designed for use on rigid or semi rigid plastic substrates. Coated film and sheeting are not covered by this guide.
B. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3.2.5.2 Prescriptive Requirements

A. Thermal Emittance and Aged Solar Reflectance

§140.3(a)1A, TABLES 140.3-B,C,D

The prescriptive requirements call for roofing products to meet the aged solar reflectance and thermal emittance in both low-sloped and steep-sloped roof applications for nonresidential buildings. A qualifying roofing product under the prescriptive approach for a nonresidential building must have an aged solar reflectance and thermal emittance greater than or equal to that the values indicated in Tables 140.3-B of the Energy Code. Table 3-2 is for hotel/motel guest rooms, and Table 3-3 is for relocatable public-school buildings where the manufacturer certifies use in all climate zones.

Table 3-2: Prescriptive Criteria for Roofing Products for Nonresidential Buildings

Climate Zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Low Sloped Aged Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Low Sloped Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Low Sloped SRI	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Steep Sloped Aged Reflectance	0.20	0.25	0.20	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Steep Sloped Emittance	0.75	0.80	0.75	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Steep Sloped SRI	16	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23

Energy Code, Table 140.3-B

Table 3-2: Prescriptive Criteria for Roofing Products for Guest Rooms of Hotel/Motel Buildings

Climate Zone (CZ)	Low-sloped Aged Reflectance	Low-sloped Emittance	Low-sloped SRI	Steep-Sloped Aged Reflectance	Steep-Sloped Emittance	Steep-Sloped SRI
CZ 1	NR	NR	NR	NR	NR	16
CZ 2	NR	NR	NR	0.20	0.75	16
CZ 3	NR	NR	NR	0.20	0.75	16
CZ 4	NR	NR	NR	0.20	0.75	16
CZ 5	NR	NR	NR	0.20	0.75	16
CZ 6	NR	NR	NR	0.20	0.75	16
CZ 7	NR	NR	NR	0.20	0.75	16
CZ 8	NR	NR	NR	0.20	0.75	16
CZ 9	0.55	0.75	64	0.20	0.75	16
CZ 10	0.55	0.75	64	0.20	0.75	16
CZ 11	0.55	0.75	64	0.20	0.75	16
CZ 12	NR	NR	NR	0.20	0.75	16
CZ 13	0.55	0.75	64	0.20	0.75	16
CZ 14	0.55	0.75	64	0.20	0.75	16
CZ 15	0.55	0.75	64	0.20	0.75	16
CZ 16	NR	NR	NR	NR	NR	16

Energy Code, Table 140.3-C

Table 3-3: Prescriptive Criteria for Roofing Products for Relocatable Public-School Buildings, Where Manufacturer Certifies Use in All Climate Zones

Roofing Products	Aged Reflectance	Emittance
Low-Sloped	0.63	0.75
SRI	75	75
Steep-Sloped	0.25	0.80
SRI	23	23

Energy Code, Table 140.3-D

Exceptions to the minimum prescriptive requirements for solar reflectance and thermal emittance:

1. Roof area covered by building-integrated photovoltaic panels and building-integrated solar thermal panels is not required to meet the cool roof requirements.
2. If the roof construction has a thermal mass like gravel, concrete pavers, stone, or other materials with a weight of at least 25 lb/ft² over the roof membrane, then it is exempt from the above requirements for solar reflectance and thermal emittance.

3. Wood-framed roofs in Climate Zones 3 and 5 with a U-factor of 0.034 are exempt from the low-sloped cool roof requirement.

Where a low-sloped nonresidential roof's aged reflectance is less than the prescribed requirement, insulation tradeoffs are available. By increasing the insulation level of a roof, a roofing product with a lower reflectance than the prescriptive requirements can be used to meet the cool roof requirements. The appropriate U-factor can be determined from Table 3-4 for nonresidential buildings based on roof type, climate zone and aged reflectance of at least 0.25.

Table 3-4: Roof/Ceiling Insulation Tradeoff for Aged Solar Reflectance

Aged Solar Reflectance	Metal Building Climate Zone 1-16 U-factor	Wood-Framed and Other Climate Zone 6, 7, and 8 U-factor	Wood Framed and Other All Other Climate Zones U-factor
0.62-0.56	0.038	0.039	0.029
0.55-0.46	0.035	0.036	0.028
0.45-0.36	0.033	0.033	0.027
0.35 -0.25	0.031	0.032	0.026

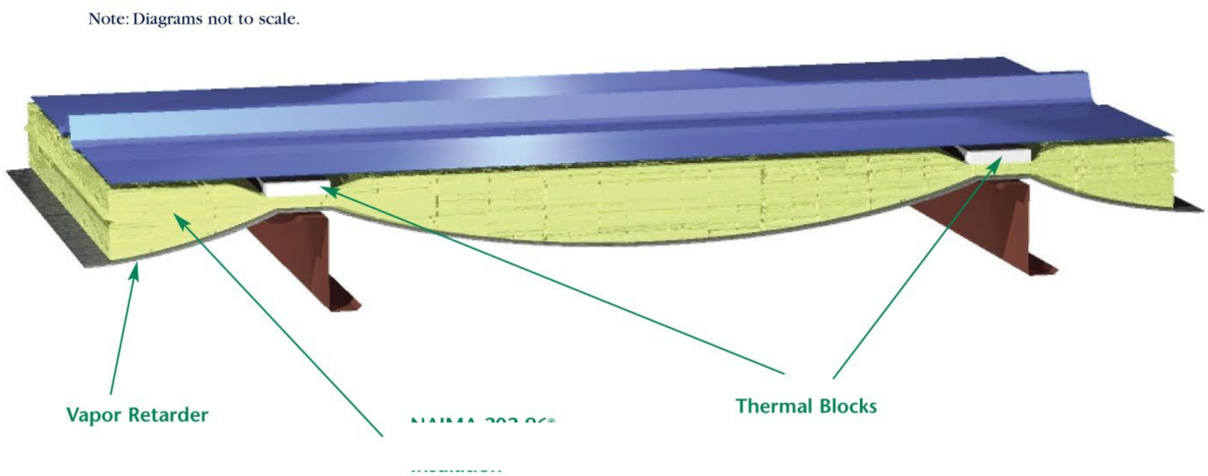
Energy Code, Table 140.3

§140.3(a)1B, TABLES 140.3-B,C,D

Under the prescriptive requirements, roofs or ceilings must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential l buildings. (See Table 3-5.) The U-factor values for exterior roofs and ceilings from Reference Appendices, Joint Appendix JA4 must be used to determine compliance with the maximum assembly U-factor requirements. Alternatively, the assembly calculator that is incorporated into the approved energy modeling software, can be used to determine U-factors for assemblies and/or components not listed in JA4 tables.

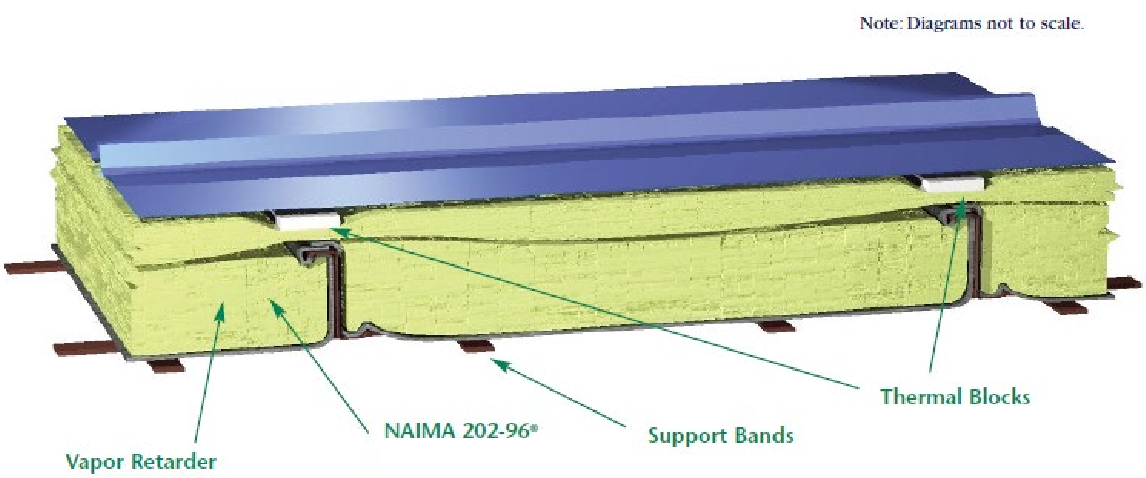
The prescriptive requirement for metal building roofs requires the entire cavity be filled with insulation. A common technique for standing seam metal roofs is to drape a layer of insulation over the purlins, using thermal blocks where the insulation is compressed at the supports. (See Figure 3-3A.) Either approach on insulation may be used in the performance approach. However, there are significant benefits to using the "filled cavity" approach as shown in Figure 3-3B.

Figure 3-3A: Standing Seam Metal Building Roof with Single Insulation Layer



Source: North American Insulation Manufacturers Association (NAIMA)

Figure 3-3B: Filled Cavity Insulation for Metal Building Roofs



Source: North American Insulation Manufacturers Association (NAIMA)

A rigid polyisocyanurate ("polyiso") thermal block with a minimum R-value of R-3.5 should be installed at the supports (a 1-inch-thick thermal block is recommended). The first rated R-value of the insulation is for faced insulation installed between the purlins. The second rated R-value of insulation represents unfaced insulation installed above the first layer, perpendicular to the purlins and compressed when the metal roof panels are attached. A supporting structure retains the bottom of the first layer at the prescribed depth required for the full thickness of insulation.

The bottom layer of insulation should completely fill the space between the purlins, and the support bands should be installed tightly to prevent the insulation from sagging.

The configuration in Figure 3-3B shown with two layers, one of R-19 and one of R-10 insulation, corresponds to the prescriptive requirement of U-0.041. ,Other insulation combinations exceeding the minimum requirement are readily achievable.

3.2.6 Performance Approach

§10-113, §140.1, TABLE 140.3

Compliance options for roofing products and insulation. See Section 3.5 and Chapter 12 for more on the performance approach.

Example 3-1

Question:

According to the provisions of the Energy Code, are cool roofs mandatory for nonresidential buildings?

Answer:

No. Cool roofs are not mandatory. The prescriptive compliance requirements depend on the climate zone, building type and roof slope. Compliance with aged solar reflectance and thermal emittance, or SRI is required per Energy Code, Tables 140.3-B, C, and D. In the performance approach, reflectance, and emittance values less than the minimum prescriptive requirements may be used; however, any deficit that results from this choice must be made up by improving other energy efficiency features in the building, which include envelope, space-conditioning system, and lighting systems.

Example 3-2

Question:

Must all roofing materials used in California, whether cool roof or not, be certified by the CRRC and labeled accordingly?

Answer:

Yes, when altering your roof, such as a new reroof or replacement of 50 percent or 2,000ft², whichever is less, then, either the prescriptive envelope component approach or the performance approach can be used for compliance. In these cases, the roof must be certified and labeled by the Cool Roof Rating Council (CRRC) for nonresidential roofs. If you are using the performance approach to receive compliance credit, you can either obtain a CRRC certification, **or** use a default solar reflectance of 0.10 and thermal emittance of 0.75. Using default values instead of CRRC certificates may result in a significant energy penalty that must be made up by increasing energy efficiency in other building features. The default solar reflectance for asphalt shingles is 0.08.

However, in the case of a roof repair, such as for a leak, the roofing product does not need to be a cool roof nor certified by the CRRC.

Example 3-3

Question:

Can I use aged solar reflectance and thermal emittance data generated by any nationally recognized and well-respected laboratory in lieu of CRRC ratings? Can in-house testing by the manufacturer be used to qualify my product?

Answer:

No. Only CRRC ratings from the product directory list can be used to establish cool roof product qualification for standards compliance. The CRRC process requires use of a CRRC-accredited laboratory (under most circumstances, an "Accredited Independent Testing Laboratory (AITL) defined by the CRRC program.) Any testing laboratory can become an AITL by following the CRRC accreditation process and satisfying the requirements. The roster of CRRC-accredited laboratories is posted on the CRRC website (http://www.coolroofs.org).

Example 3-4

Question:

Can the reflectance and emittance requirements of ENERGY STAR® cool roofs be substituted for standards requirements?

Answer

No. Only roofing products which are listed by the CRRC in its Rated Product Directory can be used to comply with the Standards. CRRC is the only organization that has met the criteria set in §10-113.

Example 3-5

Question:

Can I claim to have a cool roof, or can I get anything higher than a default reflectance, if my roof does not meet the field-applied coating performance requirements of the Energy Code?

Answer:

No, you cannot claim to have a cool roof and you cannot claim higher energy credits if your roof does not meet the coating performance requirements of the Energy Code for field-applied coatings.

Example 3-6

Question:

How does a product get CRRC cool roof certification?

Answer:

Any party wishing to have a product or products certified by CRRC should contact the CRRC toll-free (866) 465-2523 from inside the United States or (510) 482-4420, ext. 215, or email info@coolroofs.org. In addition, CRRC publishes the procedures in the *CRRC-1 Program Manual*, available for free on http://www.coolroofs.org or by calling the CRRC. Working with CRRC staff is strongly recommended.

Example 3-7

Question:

Do alterations to the roof of an unconditioned building trigger cool roof requirements?

Answer:

No, alterations to the roof of an unconditioned building do not trigger cool roof requirements. In general, the lighting requirements are the only requirements applicable for both newly constructed and altered unconditioned buildings; this includes §140.3(c), the skylight requirements. Building envelope (other than skylight requirements) and space-conditioning requirements do not apply to unconditioned buildings.

Example 3-8

Question:

What happens if I have a low-sloped roof on most of my buildings and steep-sloped roof on another portion of the roof? Do I have to meet the two different sets of rules in §140.3(a)1Ai and ii?

Answer:

Yes, your building would have to meet both the low-sloped requirement and the steep-sloped roof requirements for the respective areas.

Example 3-9

Question:

I am installing a green/garden roof (roofs whose surface is composed of soil and plants) on top of an office building. Although green/garden roofs are not cool roofs by their reflectance properties, will they be allowed under the Energy Code?

Answer:

Yes, the Energy Commission considers a green/garden roof as a roof with thermal mass on it. Under *Exception* 4 to §140.3(a)1Ai, if a garden roof has a dry unit weight of 25 lb/ft², then the garden roof is equivalent to cool roof.

3.2.7 Exterior Walls

The U-factor criteria for walls depend on the class of construction. U-factors used for compliance must be selected from Reference Appendices, Joint Appendix JA4. Alternatively, the assembly calculator that is incorporated into California Building Energy Code Compliance (CBECC) software can be used to determine U-factors for assemblies and/or components not listed in JA4.

There are five common classes of wall constructions: wood-framed, metal-framed, metal building walls, light mass, and heavy mass. (Figure 3-5.) The following provides information about these wall systems, as well as furred walls, spandrel panels and opaque curtain walls:

A. **Wood-framed walls:** As defined by the 2022 California Building Code, Type IV buildings typically have wood-framed walls. Framing members typically consist of 2x4 or 2x6 framing members spaced at 24-inch or 16-inch OC. Composite framing members and engineered wood products also qualify as wood framed walls if the framing members are nonmetallic. Reference Joint Appendix JA4, Table 4.3.1 has data for conventional wood-framed walls.

Metal-framed walls: Many nonresidential buildings require noncombustible construction, and this is often achieved with metal-framed walls. Often metal-framed walls are not structural and are used as infill panels in rigid framed steel or concrete buildings. Batt insulation is less effective for metal-framed walls (compared to wood-framed walls) because the metal framing members are more conductive. In most cases, continuous insulation is required to meet prescriptive U-factor requirements. Reference Appendices, Joint Appendix JA4, Table 4.3.3, has data for metal-framed walls.

Metal building walls: Metal building walls consist of a metal building skin that is directly attached to metal framing members. The framing members are typically positioned in a horizontal direction and spaced at about 4 feet. A typical method of insulating metal building walls is to drape the insulation over the horizontal framing members and to compress the insulation when the metal exterior panel is installed.

Light-mass walls: Light-mass walls have a heat capacity (HC) greater or equal to 7.0 but less than 15.0 Btu/°F-ft². See the definition below for heat capacity. From Reference Appendices, Joint Appendix JA4, Tables 4.3.5 and 4.3.6 have U-factor, C-factor, and heat capacity data for hollow unit masonry walls, solid unit masonry and concrete walls, and concrete sandwich panels.

Heavy-mass walls: Have a HC equal to or greater than 15.0 Btu/°F-ft². See Reference Joint Appendix JA4 for HC data on mass walls.

> *Note: For light- and high-mass walls,* ***heat capacity (HC)*** *is the amount of heat required to raise the temperature of the material by 1 degree F. In the Energy Code, it is defined as the product of the density (lb/ft^3), specific heat (Btu/lb-F), and wall thickness (ft). For instance, a 6" medium weight concrete hollow unit masonry wall has a heat capacity of 8.4 and is considered a light mass wall. The same masonry wall with solid grout that is 10 inches thick has a heat capacity of 19.7 and is considered a heavy mass wall.*

Furred walls: Are a specialty wall component, commonly applied to a mass wall type. See Figure 3-4 below. The Reference Appendices, Joint Appendix JA4 Table 4.3.5, 4.3.6, or other masonry tables list alternative walls. Additional continuous insulation layers are selected from JA4 Table 4.3.13 and calculated using either Equation 4-1 or 4-4 from JA4. The effective R-value of the furred component depends upon the framing thickness, type, and insulation level.

Figure 3-4: Brick Wall with Furring Details

Spandrel panels and **curtain walls:** These wall types consist of metalized panels, opaque or semi-translucent glass panels often hung outside structural framing to create exterior wall elements around fenestration and between floors. See Reference Appendices, Joint Appendix JA4, Table 4.3.8 for U-factor data.

For some climate zones, mass walls and metal-framed walls require continuous insulation to meet the prescriptive U-factor requirements. When this is the case, the effect of the continuous insulation is estimated by Equation 4-1 in Reference Appendices, Joint Appendix JA4.

$$U_{prop} = 1 / [(1/U_{col,A}) + R_{cont,insul}]$$

Framed or block walls can also have insulation installed between interior or exterior furring strips. The effective continuous R-value of the furring/insulation layer is shown in Table 4.3.13 of Reference Appendix JA4.

Example 3-10

Question :

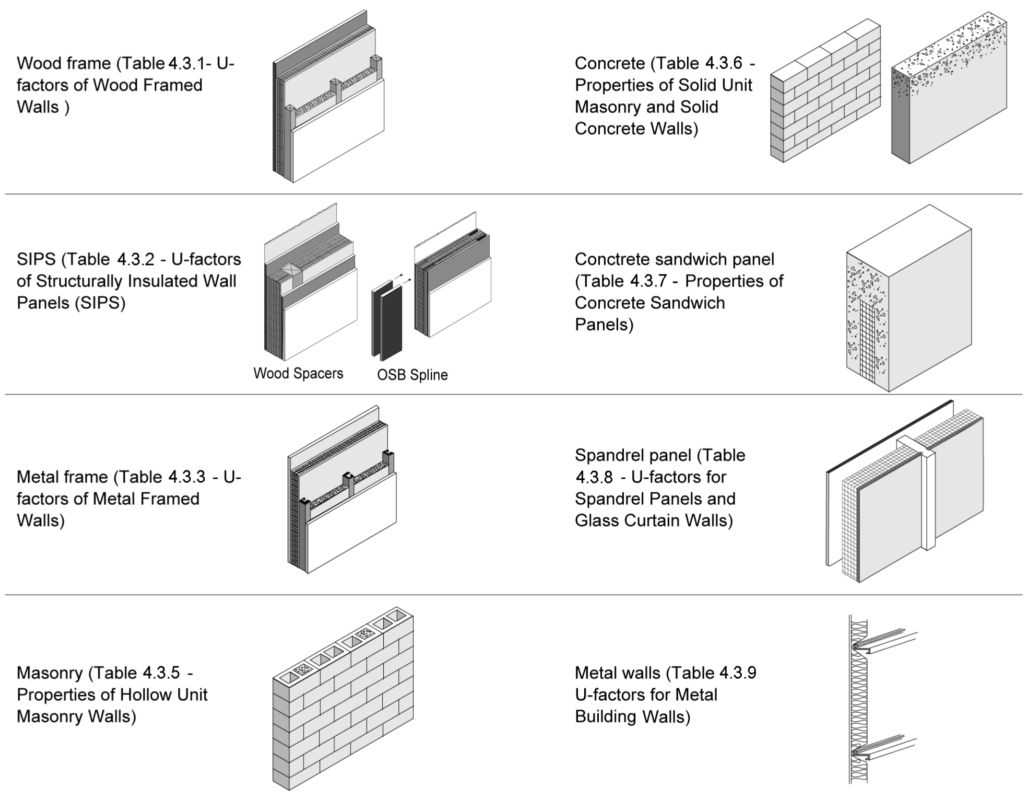
An 8-inch (20 cm) medium-weight concrete block wall with uninsulated cores has a layer of 1 inch (25 mm) thick exterior polystyrene continuous insulation with an R-value of R-5. What is the U-factor for this assembly?

Answer:

From Reference Appendices, Joint Appendix Table 4.3.5, the U-factor for the block wall is 0.53. From Equation 4-1, the U-factor is calculated as:

U= 1 / [(1/0.53) + 5] = 0.145

Figure 3-5: Classes of Wall Construction



Source: Reference Appendices JA4.3

3.2.8 Mandatory Requirements

A. Wall Insulation

§110.8, §120.7(b)

In addition to the mandatory requirements in §110.8 for all buildings, Nonresidential, high–rise residential, hotels and motels must also meet the requirements in §120.7

The opaque portions of walls that separate conditioned spaces from unconditioned spaces or ambient air shall meet these applicable requirements.

1. Metal Building: Weighted average U-factor of U-0.113 (single layer of R-13 batt insulation).
2. Metal-Framed: Weighted average U-factor of U-0.151 (R-8 continuous insulation, or R-13 batt insulation between studs and 1/2” of continuous rigid insulation of R-2). It may be possible to meet the area-weighted average U-factor without continuous insulation if the appropriate siding materials are used.

3. Light Mass Walls: 6 inches or greater hollow core concrete masonry unit having a U-factor not exceeding 0.440 (partially grouted with insulated cells).
4. Heavy Mass Walls: 8 inches or greater hollow core concrete masonry unit having a U-factor not exceeding 0.690 (solid grout concrete, normal weight, 125 lb/ft^3).
5. Wood-Framed and Others: Weighted average U-factor of U-0.110 (R-11 batt insulation).
6. Spandrel Panels and Curtain Wall: Weighted average U-factor of U-0.280.

Exception to Section 120.7: Buildings designed as data centers with high, constant server loads are exempt from the mandatory minimum requirements. To qualify for this exception, it should have a design computer room process load of 750 kW or greater.

3.2.9 Prescriptive Requirements

§140.3(a)2, TABLES 140.3-B,C,D

Under the prescriptive requirements, exterior walls must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential buildings in Tables 140.3-B,C,D (see Table 3-6).

The U-factor for exterior walls from Reference Appendices, Joint Appendix JA4 must be used to determine compliance with the assembly U-factor requirements. The Energy Code does not allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of Reference Appendices, Joint Appendix JA4; only U-factors may be used to demonstrate compliance.

For metal-framed walls with insulation between the framing sections, continuous insulation may need to be added to meet the U-factor requirements of the Energy Code. For light mass walls, insulation is not required for buildings in South Coast climates (i.e., climate zones 5-9) but is required for other climates. For heavy mass walls, insulation is not required for buildings in Central Coast (i.e., climate zones 3-5) or South Coast (i.e., climate zones 6-9) climates but is required for other climates.

Table 3-6a: Wall U-Factor Requirements by Building Type (Climate Zones 1 through 8)

Climate Zones	1	2	3	4	5	6	7	8
Nonresidential Metal Building	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061
Nonresidential Metal- Frame	0.060	0.055	0.071	0.055	0.055	0.060	0.060	0.055
Nonresidential Mass Light	0.196	0.170	0.278	0.227	0.44	0.44	0.44	0.44
Nonresidential Mass Heavy	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690
Nonresidential Wood-Frame	0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102
Hotel/Motel Metal building	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
Hotel/Motel Metal -frame	0.069	0.069	0.069	0.069	0.069	0.069	0.105	0.069
Hotel/Motel Mass Light	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227
Hotel/Motel Mass Heavy	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690
Hotel/Motel Wood-Frame	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Relocatable Public Schools Metal Building	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
Relocatable Public Schools Metal -Frame	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
Relocatable Public Schools Mass /7.0<HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Relocatable Public Schools Wood Frame	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
Relocatable Public Schools All Other Walls	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

Table 3-6b: Wall U-Factor Requirements by Building Type (Climate Zones 9 through 16)

Climate Zones	9	10	11	12	13	14	15	16
Nonresidential Metal Building	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Nonresidential Metal- Frame	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Nonresidential Mass Light	0.44	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Nonresidential Mass Heavy	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
Nonresidential Wood-Frame	0.059	0.059	0.045	0.059	0.059	0.059	0.042	0.059
Hotel/Motel Metal building	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
Hotel/Motel Metal -frame	0.069	0.069	0.069	0.069	0.069	0.069	0.048	0.069
Hotel/Motel Mass Light	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Hotel/Motel Mass Heavy	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
Hotel/Motel Wood-Frame	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
Relocatable Public Schools Metal Building	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
Relocatable Public Schools Metal -Frame	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
Relocatable Public Schools Mass /7.0<HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Relocatable Public Schools Wood Frame	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
Relocatable Public Schools All Other Walls	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

3.2.10 Demising Walls

3.2.10.1 Mandatory Insulation for Demising Walls

§120.7(b)7, §140.3(a)3 and Exception to §140.3(a)5A

Demising walls separate conditioned space from enclosed unconditioned space. The insulation requirements include:

- Wood-framed: minimum of R-13 insulation (or have an equivalent U-factor of 0.099) between framing members.
- Metal-framed: minimum R-13 insulation (or a U-factor no greater than 0.151) between framing members plus R-2 continuous insulation.
- If it is not a framed assembly (constructed of brick, concrete masonry units, or solid concrete), then no insulation is required.

This requirement applies to buildings meeting compliance with either the prescriptive or performance approach.

Note: Window area in demising walls is not counted as part of the window area for this requirement. Demising wall area is not counted as part of the gross exterior wall area or display perimeter for this requirement.

3.2.11 Exterior Doors

When an exterior door has 25 percent or more glazed area it is considered fenestration. See more on fenestration in Section 3.3.

3.2.11.1 Mandatory Requirements

§110.6(a)1

Manufactured exterior doors shall have an air infiltration rate not exceeding:

- 0.3 cfm/ft^2 of door area for nonresidential single doors (swinging and sliding).
- 1.0 cfm/ft^2 of door area for nonresidential double doors (swinging).

3.2.11.2 Prescriptive Requirements

§140.3(a)7, TABLES 140.3-B,C,D

The Energy Code define prescriptive requirements for exterior doors in Tables 140.3-B and 140.3-C. For swinging doors, the maximum U-factor is 0.70, and for non-swinging doors, the maximum allowed U-factor is 1.45 in climate zones 2 through 15 and 0.50 in climate zones 1 and 16. Refer to Energy Code, Table 140.3-B, 140.3-C, and 140.3-for exterior door U-factor requirements.

The swinging door requirement corresponds to uninsulated double-layer metal swinging doors. The 1.45 swinging door U-factor requirement corresponds to insulated single-layer metal doors or uninsulated single-layer metal roll-up doors and fire-rated doors. The 0.50 U-factor requirement for climate zones 1 and 16 corresponds to wood doors with a minimum nominal thickness of 1 ¾ inches. For more information, consult Reference Appendices, Joint Appendix JA4, Table 4.5.1.

When glazing area is 25 percent or more of the entire door area, it is then defined as a fenestration product in the Energy Code, and the entire door area is modeled as a fenestration unit. If the glazing area is less than 25 percent of the door area, the glazing must be modeled as the glass area plus two inches in each direction of the opaque door surface (to account for a frame). However, exterior doors are part of the gross exterior wall area and must be considered when calculating the window to wall ratio.

3.2.12 Floors

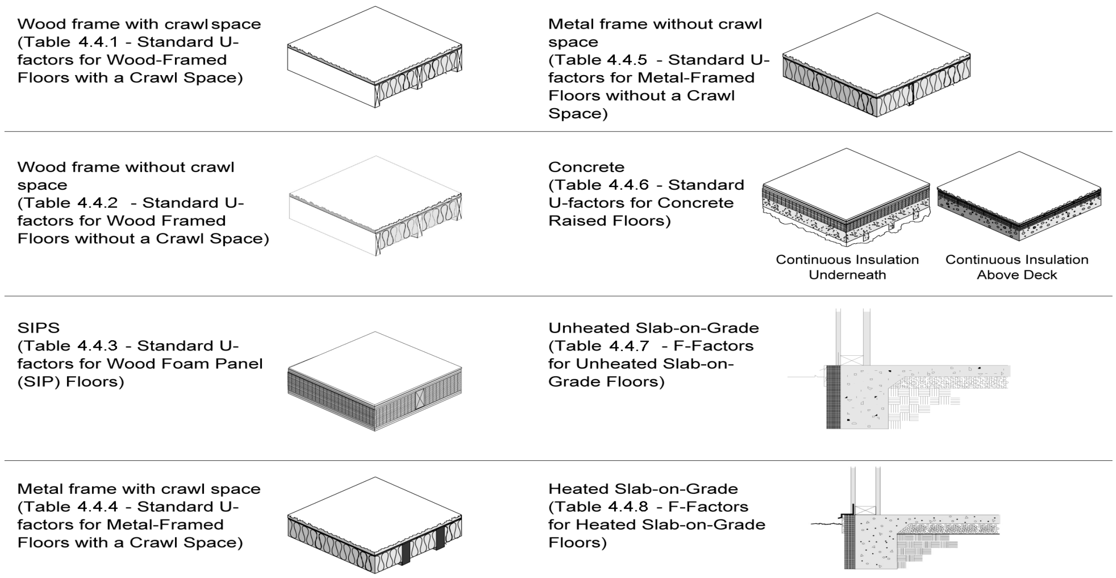
The U-factor criteria for concrete raised floors depend on whether the floor is a mass floor or not. A mass floor is one constructed of concrete with a heat capacity (HC) greater than or equal to 7.0 Btu/°F-ft².

Insulation levels for nonresidential concrete raised floors with HC ≥ 7.0 using U-factor for compliance, from Reference Appendices, Joint Appendix JA4, Table 4.4.6, are equivalent to no insulation in climate zones 3-10 and associated U-factors to continuous insulation of R-8 in climate zones 1, 2, 11 through 15; and R-15 in climate zone 16.

To determine the U-factor insulation levels for hotel/motel concrete raised floors, use the U-factors that are associated with R-8 continuous insulation in climate zones 7 through 9; R-15 in climate zones 3-5 and 11-13; with additional insulation required in climate zones 1, 2, 14 and 16.

Table 4.4.6 from Reference Appendices, Joint Appendix JA4 is used with mass floors while Tables 4.4.1 through 4.4.5 are used for non-mass floors. (See Figure 3-6.)

Figure 3-6: Classes of Floor Constructions



Source: Reference Appendix JA4.4

3.2.12.1 Mandatory Requirements

A. Insulation Requirements for Heated Slab Floors

§110.8(g), TABLE 110.8-A

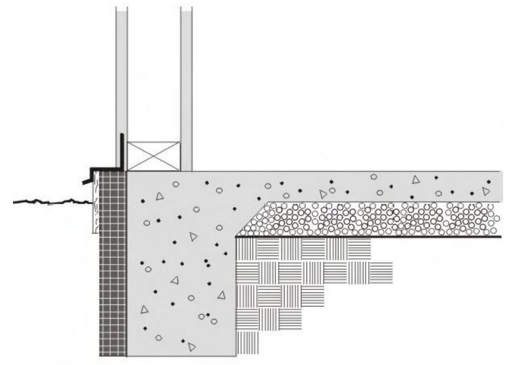
Heated slab-on-grade floors must be insulated according to the requirements in Table 110.8-A of the Energy Code (Table 3-8). The top of the insulation must be protected with a rigid shield to prevent intrusion of insects into the building foundation, and the insulation must be capable of withstanding water intrusion.

A common location for the slab insulation is on the foundation perimeter. Insulation that extends downward to the top of the footing is acceptable. Otherwise, the insulation must extend downward from the level of the top of the slab, down 16 inches (40 cm) or to the frost line, whichever is greater.

For below-grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.

Another option is to install the insulation inside the foundation wall and between the heated slab and exterior wall. In this case insulation must extend downward to the top of the footing and then extend horizontally inward, under the slab, a distance of 4 feet toward the center of the slab. R-5 vertical insulation is required in all climates except climate zone 16, which requires R-10 of vertical insulation and R-7 horizontal insulation.

Figure 3-7: Perimeter



Note: The California Mechanical Code should be consulted when constructing a heated slab.

Table 3-8: Slab Insulation Requirements for Heated Slab Floors

Insulation Location	Insulation Orientation	Installation Requirements	Climate Zone	Insulation R-Value
Outside edge of heated slab, either inside or outside the foundation wall	Vertical	From the level of the top of the slab, down 16 inches or to the frost line, whichever is greater. Insulation may stop at the top of the footing where this is less than the required depth. For below-grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.	1 – 15	5
			16	10
Between heated slab and outside foundation wall	Vertical and Horizontal	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plain view.	1 – 15	5
			16	10 vertical and 7 horizontal

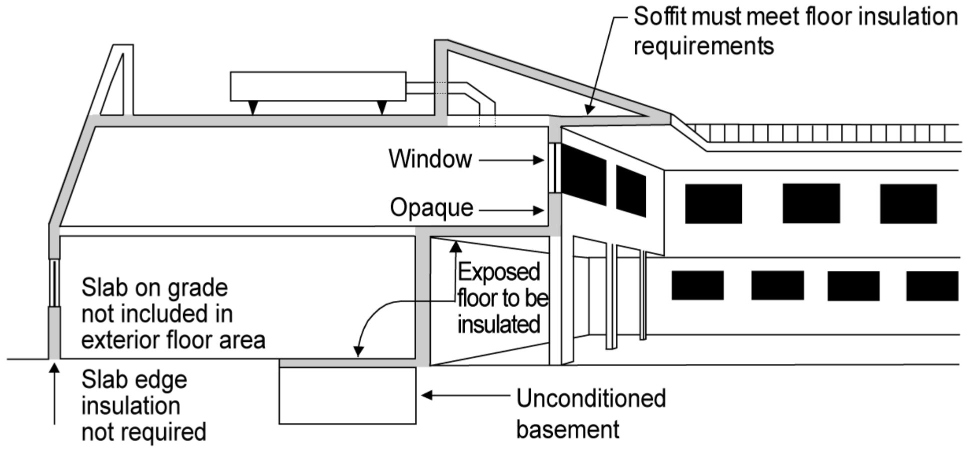
Energy Code, Table 110.8-A

B. Floor and Soffit Insulation

§110.8(g), §120.7(c)

1. Raised Mass Floors: A minimum of 3 inches of lightweight concrete over a metal deck or the weighted average U-factor of the floor assembly shall not exceed U-0.269.
2. Other Floors: Weighted average U-factor of U-0.071.
3. Heated Slab Floor: A heated slab floor shall be insulated to meet the requirements of §110.8(g).

Figure 3-7: Requirements for Floor/Soffit Surfaces



3.2.12.2 Prescriptive Requirements

A. Exterior Floors and Soffits

§140.3(a)4, TABLES 140.3-B,C,D

Under the prescriptive requirements, exterior floors and insulated soffits must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential and hotel/motel buildings and relocatable public school buildings in Tables 140.3-B,C,D (Table 3-9). The U-factor for exterior floors and soffits from Reference Appendices, Joint Appendix JA4 shall be used to determine compliance with the maximum assembly U-factor requirements. The Energy Code does not allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of JA4; only U-factors may be used to demonstrate compliance. For metal-framed floors, batt insulation between framing section may need continuous insulation to be modeled and installed on the interior or exterior to meet the U-factor requirements of the Energy Code. See Energy Code, Tables 140.3-B, 140.3-C, and 140.3-D.

3.3 Fenestration (Window/Skylight/Glazed Door)

Choosing energy efficient windows, glazed doors, and skylights is one of the most important decisions for any high-performance project. The use of high-performance fenestration can actually reduce energy consumption by decreasing the lighting and heating and cooling loads in nonresidential and hotel/motel buildings. The size, orientation, and types of fenestration products can dramatically affect overall energy performance.

The Energy Code specifies the mandatory and prescriptive features of fenestration products, the performance of fenestration, ratings and labeling by the National Fenestration Rating Council (NFRC), and details on daylighting through skylights.

3.3.1 Fenestration Definitions

Windows. A window is a vertical fenestration product that is an assembled unit consisting of a frame and sash component holding one or more pieces of glazing. Window performance is measured with the U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT).

Windows are considered part of an exterior wall when the slope is 60° or more. When the slope of fenestration is less than 60°, the glazing is considered a skylight and part of the roof.

Skylights and Tubular Daylight Devices. Skylights and tubular daylight devices (TDD) are an exceptional source of daylight and passive solar heating, illuminating rooms with direct and indirect sunlight. In addition, when used appropriately, daylighting can increase the quality of light in a room and reduce dependence upon electrical lighting. Skylights and TDDs don't typically have the same thermal properties as vertical fenestration and can be prone to greater heat loss in winter and solar heat gain during the summer. When a building designer optimizes the whole envelope glazing arrangement for daylight and thermal control, significant heating and cooling energy savings can be realized, especially when skylights and TDDs are energy efficient.

Glazed Doors. Glazed door is an exterior door having a glazed area of 25 percent or more of the area of the door. When the door has less than 25 percent glazing material, it is no longer considered a glazed door. (See exterior doors in previous section). All glazed areas will be counted toward the overall glazed area of the conditioned space in any calculations.

There are two options for measuring the glazed area of a door: Count the entire door area for glazed doors or count the area of the glazing in the door plus a 2-inch frame around the glass (i.e., if you have 1-foot by 1-foot glazing in a door you would measure the area as 1-foot 4-inches by 1-foot 4-inches).

3.3.2 Fenestration Categories

A. **Manufactured fenestration** is a fenestration product constructed of materials that are factory-cut or otherwise factory-formed with the specific intention of being used to fabricate a fenestration product. Knocked down or partially assembled products may be sold as a fenestration product when provided with temporary and permanent labels, as described in §10-111, or as a site-built fenestration product when not provided with temporary and permanent labels, as described in §10-111.

B. **Site-built fenestration** is designed to be field-glazed or field-assembled units, using specific factory-cut or other factory-formed framing, and glazing units that are manufactured with the intention of being assembled at the construction site. These include storefront systems, curtain walls or large-track sliding glass walls, and atrium roof systems.

C. **Field-fabricated fenestration** is when the windows are fabricated at the building site from elements that are not sold together as a fenestration product (that is, separate glazing, framing, and weather stripping elements). Field-fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked-down products, sunspace kits, and curtain walls).

3.3.3 Additional Fenestration Definitions

Reference Appendices, Joint Appendix JA1 lists additional terms that relate to fenestration.

A. **Center of Glass.** U-factor, SHGC, and VT are measured only through glass at least 2.5 inches from the edge of the glass or dividers.

B. **Clear glass** has little, if any, observable tint.

C. **Chromogenic** is a class of switchable glazing which includes active materials (e.g., electrochromic) and passive materials (e.g., photochromic and thermochromic) permanently integrated into the glazing assembly

D. **Divider (Muntin)**. An element that actually or visually divides different lites of glass. It may be a true divided lite, between the panes, and/or applied to the exterior or interior of the glazing.

E. **Double Pane Window.** Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by space (generally 1/4" [6 mm] to 3/4" [18 mm]) filled with air or other inert gas. Two panes of glazing laminated together do not constitute double-pane glazing

F. **Dynamic Glazing.** Glazing systems that have the ability to reversibly change their performance properties, including U-factor, solar heat gain coefficient (SHGC), and/or visible transmittance (VT) between well-defined end points. Includes active materials (electrochromic) and passive materials (photochromic and thermochromic) permanently integrated into the glazing assembly. Electrochromatic glass darkens by demand or lightens up when more free daylight or solar heat is desired. Improved glazing decreases the SHGC in the summer and reduces heat loss in the winter and has the ability to reversibly change their performance properties, including U-factor, SHGC, and/or VT between well-defined end points.

G. **Integrated shading systems.** A class of fenestration products including an active layer: for example, shades, louvers, blinds, or other materials permanently integrated between two or more glazing layers and that has the ability to reversibly change performance properties, including U-factor, SHGC, and/or VT between well-defined end points.

H. **Fixed glass.** The fenestration product cannot be opened.

I. **Gap Width.** The distance between glazing in multi-glazed systems (e.g., double-or triple-glazing). This dimension is measured from inside surface to inside surface. Some manufacturers may report "overall" IG unit thickness which is measured from outside surface to outside surface.

J. **Insulating glass unit (IG Unit)**. An IG unit includes the glazing, spacer(s), films
(if any), gas infills, and edge caulking.

K. **Hard Coat.** A pyrolytic low-e coating that is generally more durable but less effective than a soft coat. See separate glossary term for low-e coating.

L. **Light or Lite**. A layer of glazing material, especially in a multi-layered IG unit. Referred to as panes in §110.6 when the lites are separated by a spacer from inside to outside of the fenestration.

M. **Low-emissivity (Low-e) Coatings.** Low-emissivity coatings are special coatings applied to the second, third or fourth surfaces in double-glazed windows or skylights. As the name implies the surface has a low emittance. This means that radiation from that surface to the surface it "looks at" is reduced. Since radiation transfer from the hot side of the window to the cool side of the window is a major component of heat transfer in glazing, low-e coatings are very effective in reducing the U-factor. They do nothing, however, to reduce losses through the frame.

   Low-e coatings can be engineered to have different levels of solar heat gain. Generally, there are two kinds of low-e coatings:

   1. Low solar gain low-e coatings are formulated to reduce air conditioning loads. Fenestration products with low solar gain low-e coatings typically have an SHGC of 0.40 or less. Low-solar gain low-e coatings are sometimes called spectrally selective coatings because they filter much of the infrared and ultra-violet portions of the sun's radiation while allowing visible light to pass through.
   2. High solar gain low-e coatings, by contrast, are formulated to maximize solar gains. Such coatings would be preferable in passive solar applications or where there is little need for air conditioning.

   Another advantage of low-e coatings, especially low solar gain low-e coatings, is that when they filter the sun's energy, they generally remove between 80 percent and 85 percent of the ultraviolet light that would otherwise pass through the window and damage fabrics and other interior furnishings.

N. **Mullion**. A frame member that is used to join two individual windows into one fenestration unit.

O. **Nonmetal Frame**. Includes vinyl, wood, or fiberglass. Vinyl is a polyvinyl chloride (PVC) compound used for frame and divider elements with a significantly lower conductivity than metal and a similar conductivity to wood. Fiberglass has similar thermal characteristics. Non-metal frames may have metal strengthening bars entirely inside the frame extrusions or metal-cladding only on the surface.

P. **Operable**. The fenestration product can be opened for ventilation.

Q. **Soft Coat**. A low-e coating applied through a sputter process. See separate glossary term for low-e coating.

R. **Solar Heat Gain Coefficient (SHGC).** A measure of the relative amount of heat gain from sunlight that passes through a fenestration product. SHGC is a number between zero and one that represents the ratio of solar heat that passes through the fenestration product to the total solar heat that is incident on the outside of the window. A low SHGC number (closer to 0) means that the fenestration product keeps out most solar heat. A higher SHGC number (closer to 1) means that the fenestration product lets in most of the solar heat. SHGC or $SHGC_t$ is the SHGC for the total fenestration product and is the value used for compliance with the Standards.

S. **Spacer or Gap Space.** A material that separates multiple panes of glass in an IG unit.

T. **Thermal Break Frame.** Includes metal frames that are not solid metal from the inside to the outside, but are separated in the middle by a material, usually vinyl or urethane, with a significantly lower conductivity.

U. **Tinted**. Darker gray, brown, or green visible tint. Also, low-e or IG unit with a VT less than 0.5.

V. **U-factor.** A measure of how much heat can pass through a construction assembly or a fenestration product. The lower the U-factor, the more energy efficient the product is. The units for U-factor are Btu of heat loss each hour per square foot (ft^2) of window area per degree Fahrenheit (°F) of temperature difference (Btu/hr-ft^2-°F). U-factor is the inverse of R-value. The U-factor considers the entire product, including losses through the center of glass, at the edge of glass where a metal spacer typically separates the double-glazing panes, losses through the frame, and through the mullions. For metal-framed fenestration products, the frame losses can be significant.

W. **Visible Transmittance (VT)** is the ratio of visible light transmitted through the fenestration. The higher the VT rating, the more light is allowed through a window.

X. **Window Films** are composed of a polyester substrate to which a special scratch resistant coating is applied on one side, with a mounting adhesive layer and protective release liner applied to the other side.

Example 3-11

Question:
What constitutes a double-pane window?

Answer:
Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by a space [generally ¼ inch (6 mm) to ¾ inch (18 mm)] filled with air or other inert gases. Two panes of glazing laminated together do not constitute double-pane glazing but are treated as single pane.

3.3.4 Mandatory Requirements

§10-111, §10-112, §110.6(a)

The mandatory requirements for windows, glazed doors, and skylights address product certification and labeling, the air-tightness of the units (air leakage), how to determine the U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT).

A fenestration product or glazed door, other than field-fabricated fenestration products and field-fabricated glazed doors, may be installed if an independent certifying organization approved by the Energy Commission has certified that the product complies or if the manufacturer has certified to the Energy Commission by using a default label.

3.3.5 Certification and Labeling

§10-111 §10.112 and §110.6
Reference Nonresidential Appendices NA6

The Administrative Regulations §10-111 and §110.6 require that fenestration products have labels that list the U-factor, SHGC, VT and the method used to determine those values. The label must also certify that the fenestration product meets the requirements for air leakage from §110.6(a)1.

A. Manufactured (Factory-Assembled) Fenestration Label Certificates

Each manufactured (factory-assembled) fenestration product must have a clearly visible temporary label attached to it (Figure 3-8), which is not to be removed before inspection by the enforcement agency. The manufacturer rates and labels its fenestrations products for U-factor, SHGC and VT.

The manufacturer can choose to have the fenestration product rated and labeled in accordance with the NFRC Rating Procedure (NFRC 100 for U-factors and NFRC 200 for SHGC and VT). If the manufactured fenestration product is rated using the NFRC rating procedure, it must also be permanently labeled in accordance with NFRC procedures.

Figure 3-8: NFRC Manufactured Label

B. Default Temporary Label

Fenestration product manufacturers can choose to use default performance values for U-factors in Table 110.6-A and SHGC in Table 110.6-B. (Table 3-10 and Table 3-11) For fenestration products requiring a VT value, assume a value of 1.0 as specified in the Reference Appendices, Nonresidential Appendix NA6. The manufacturer must attach a temporary label to each window (See Figure 3-9), and manufacturer specification sheets or cut sheets must be included with compliance documentation. An NRCC-ENV-E will be required to document the thermal performance if no default temporary labels are attached to the window units.

There is no exact format for the default temporary label. It must be clearly visible and large enough to be clearly visible from 4 feet for the enforcement agency field inspector to read easily. It must include all information required by the regulations. The minimum suggested label size is 4-inches x 4-inches, and the label must have the following words at the bottom of the label.

> *"Product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2022 California Building Energy Efficiency Standards for Residential and Nonresidential Buildings."*

If the product claims the default U-factor for a thermal-break product, the manufacturer must certify that the thermal-break criteria upon which the default value is based are met by placing a check in the check box:

1. Air space 7/16 inch or greater
2. For skylights, the label must indicate the product was rated with a built-in curb

3. Meets thermal-break default criteria

Figure 3-9:
Sample Default Temporary Label

2022 California Energy Commission Default Label
XYZ Manufacturing Co.

Key Features:	☐ Doors	☐ Double-Pane
	☐ Skylight	☐ Glass Block
Frame Type	**Product Type:**	**Product Glazing Type:**
☐ Metal	☐ Operable	☐ Clear
☐ Non-Metal	☐ Fixed	☐ Tinted
☐ Metal, Thermal Break	☐ Greenhouse/Garden Window	☐ Single-Pane
☐ Air space 7/16 in. or greater ☐ With built-in curb ☐ Meets Thermal-Break Default Criteria	----------	To calculate VT see NA6
California Energy Commission Default U-factor =	**California Energy Commission** Default SHGC =	**California Energy Commission** Calculated VT =

Product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2022 Energy Standards for Residential and Nonresidential Buildings.

For the visible transmittance (VT) of diffusing skylights that is not covered by NFRC 200 or NFRC 203, a test report should be included using the ASTM E972 method.

C. Component Modeling Approach (CMA)

NFRC has developed a performance base calculation, the *component modeling approach* (CMA), to make the rating process quick and simple. This serves as an energy ratings certification program for fenestration products used in nonresidential projects. The CMA allows users to assemble fenestration products in a virtual environment. CMA draws data for NFRC-approved components from online libraries choosing from preapproved glazing, frame, and spacer components. CMA users are able to obtain preliminary ratings for various configurations of their designs. CMA is a fair, accurate, and credible method based on NFRC 100 and 200 program documents, which are verified by third-party rating procedures. This tool helps users to:

1. Design energy-efficient windows, curtain wall systems, and skylights for high-performance building projects.
2. Determine whether a product meets the specifications for a project and local/state building energy codes.
3. Model different fenestration designs to compare energy performance.

Once the user is satisfied with the product, they create a bid report containing the data for all fenestration products to be reviewed. The windows are then built, either on-site or in a factory. The final products are reviewed and are rated by an NFRC-approved calculation entity (ACE) and a license agreement is signed with NFRC. Then the NFRC issues a CMA label certificate for the project. This label certificate is a document that lists the certified fenestration ratings at the NFRC standard testing size for the entire building project. Once approved, the CMA label certificate is available online immediately. This certificate serves as code compliance documentation for fenestration energy performance, and the certified products may be applied to future projects without repeating the certification process.

Benefits of CMA.

CMA provides facility managers, specifiers, building owners, and design teams with a simple method for designing and certifying the energy performance of fenestration systems for their buildings without having to test every possible variation of glazing and framing. This is significantly less expensive than building sample wall sections and testing them in a large test enclosure. There are several additional advantages gained by using the CMA:

1. CMA's online tool has the ability to output a file with values for use in building energy analysis software programs.
2. The program can export detailed information for angular-dependent SHGC and VT values, seamlessly transferring the data to the analytical software.
3. A 2010 study[1] conducted in California demonstrated that fenestration modeled with the CMA program can provide an increase in compliance margins by as much as 11.7 percent over the Energy Standard's default calculation methods.
4. CMA can help demonstrate above-code performance, which is useful for environmental rating programs such as Leadership in Energy and Environmental Design (LEED™) or local green building programs.

Use of the CMA can lead to a more efficient building and enable cost savings due to more accurate fenestration performances and potential energy benefits from above-code utility incentives. Details are available at www.NFRC.org.

Figure 3-10: NFRC - CMA Label Certificate, Page 1

NATIONAL FENESTRATION RATING COUNCIL
LABEL CERTIFICATE

PROJECT INFORMATION

LABEL CERTIFICATE ID: ***XYZ-001*** Issuance Date: mm/dd/yyyy

This is to be completed by an NFRC Approved Calculation Entity (ACE), based on information provided by the Specifying Authority and calculated in accordance with NFRC procedures.

PROJECT LOCATION:

Address: ______________________________.

City: ____________, State, __________, Zip code: _____.

Contact person: ________________, Title: ____________.

Phone: ______, Facsimile: ______, Email: ____________.

Project name (optional): __________, Designer (optional): __________.

1 Study conducted by the Heschong Mahone Group for NFRC, "Compared to alternative fenestration rating values detailed in California's Title 24, Using CMA provides a maximum increase of 11.7 percent in energy compliance margins. This means that compared to other available options, CMA provides the most accurate values on window energy and visible performance."

Figure 3-11: NFRC - CMA Label Certificate, Page 2

PRODUCT LISTING

FOR CODE COMPLIANCE

LABEL CERTIFICATE ID: ***XYZ-001*** Issuance Date: mm/dd/yyyy

NFRC CERTIFIED PRODUCT RATING INFORMATION:*

The NFRC Certified Product Rating Information listed here is to be used to verify that the ratings meet applicable energy code requirements.

PRODUCT LISTING:

						CERTIFIED Performance Rating at NFRC Model Size		
CPD ID	Total Area	Name	Framing Ref	Glazing Ref	Spacer Ref	U**	SHGC**	VT**
	ft^2					Btu/ hr·ft²·°F	-	-
P-PL-010	88.89	PL-2200 / PL-2210	FA-PL2210	GA-TT-001	SA-AM-001	0.53	0.58	0.66
P-PL-005	192.67	PL-3400 / PL-3401	FA-PL3401	GA-TT-001	SA-AM-002	0.56	0.57	0.65
P-PL-012	382.22	PL-5700 / PL-5720	FA-PL5720	GA-TO-002	SA-AM-001	0.52	0.21	0.30
P-PL-002	60.00	PL-1100 / PL-1152	FA-PL1152	GA-TT-001	SA-AM-001	0.42	0.51	0.62
P-PL-022	525.00	PL-9900 / PL-9915	FA-PL9915	GA-TO-003	SA-AM-002	0.45	0.15	0.19

D. Fenestration Certificate NRCC-ENV-E

For nonrated products where no default label certificates are placed on the fenestration product, use the NRCC-ENV-E to document thermal performances of each fenestration product that results in a different U-factor, SHGC, and VT. One certificate will suffice when all the windows are the same.

The NRCC-ENV-E should indicate the total amount of non-NFRC-rated fenestration products throughout the project. The locations and orientations where fenestration products are being installed should be indicated on the drawings and in a fenestration schedule that lists all fenestration products.

The NRCC-ENV-E should clearly identify the appropriate table or equation that is used to determine the default U-factor and SHGC and, if applicable, the center of glass, $SHGC_C$, used in calculating the $SHGC_{fen}$. Manufacturer's documentation of these product characteristics that list the center-of-glass values must also be attached to the NRCC-ENV-E and located at the job site for verification.

E. Site-Built Label Certificates

Site-built fenestration is field-assembled using specific factory-cut or factory-formed framing and glazing units that are manufactured with the intention of being assembled at the construction site or glazing contractor's shop.

1. For site-built skylight fenestration totaling 200 ft^2 or greater, or for site-built vertical fenestration being used in newly constructed buildings, the glazing contractor or specifier must generate a NFRC label certificate from either approach listed below:
   a. A NFRC label certificate generated by the CMA computer program.
   b. Default to the U-factor values from Table 110.6-A, the SHGC values from 110.6-B, and for VT values, use the method specified in NA6.
2. For site-built skylight fenestration totaling less than 200 ft^2 or for site-built vertical fenestration being used in an alteration, the glazing contractor or specifier must comply with one of the following:
   a. A NFRC label certificate generated by the CMA computer program.
   b. The center-of-glass values from the manufacturer's product literature to determine the total U-factor, SHGC and VT. (See Reference Nonresidential Appendix NA6 - the *Alternative Default Fenestration Procedure*).
   c. The U-factor values from Table 110.6-A and SHGC values from Table 110.6-B. For VT values, use the method specified in NA6.

NA6 calculations are based on center-of-glass (COG) values from the manufacturer. For example, when using a manufacturer's SHGC center-of-glass specification of 0.27, the NA6 calculation results in an overall SGHC value of 0.312, which may be rounded to 0.31. Rounding to the nearest hundredth decimal place is acceptable to determine the overall fenestration efficiency value with either the prescriptive or performance approach.

Site-built certificates should be filed at the contractor's project office during construction or in the building manager's office. Site-built fenestration has multiple responsible parties. The steps of producing site-built fenestration are as follows:

1. Architects and/or engineers design the basic glazing system by specifying the components, the geometry of the components, and, sometimes, the assembly method.
2. An extrusion manufacturer provides the mullions and frames that support the glazing and is responsible for thermal breaks.

3. A glazing manufacturer provides the glazing units, cut to size and fabricated as insulated glass (IG) units. The glazing manufacturer is responsible for tempering or heat strengthening, the tint of the glass, any special coatings, the spacers, and the sealants.
4. A glazing contractor (usually a subcontractor to the general contractor) puts the system together at the construction site, or the contractor’s shop and is responsible for many quality aspects. Predetermining the energy performance of site-built fenestration as a system is more challenging than for manufactured units.
5. One of the parties (architect, glazing contractor, extrusion manufacturer, IG fabricator, or glass manufacturer) must take responsibility for testing and labeling of the site-built fenestration system under the most recent NFRC 100 procedure. The responsible party must obtain a label certificate as described in §10-111.
6. The glazing contractor or other appropriate party assumes responsibility for acquiring the NFRC label certificate. Each label certificate has the same information as the NFRC temporary label for manufactured products but includes other information specific to the project, such as the name of the glazing manufacturer, the extrusion contractor, the places in the building where the product line is used, and other details.

It is typical for the glazing contractor to assume responsibility and to coordinate the certification and labeling process. The design team may include language in the contract with the general contractor that requires that the general contractor be responsible. The general contractor typically assigns this responsibility to the glazing contractor once the responsible party has established a relationship with the NFRC.

It is not necessary to complete the NFRC testing and labeling prior to completing the building permit application. Designers should specify the type of glass and whether the frame has a thermal break or is thermally improved. Plans examiners should verify that the fenestration performance shown in the plans and used in the compliance calculations is reasonable and achievable, by consulting the default values for U-factor and SHGC in Reference Nonresidential Appendix NA6.

F. Field-Fabricated Fenestration and Field-Fabricated Exterior Door

Field-fabricated fenestration is fenestration assembled on site that does not qualify as site-built fenestration. It includes windows where wood frames are constructed from raw materials at the building site, salvaged windows that do not have an NFRC label or rating, and other similar fenestration items.

No attached labeling is required for field-fabricated fenestration products; only the NRCC-ENV-E with the default values is required. Field-fabricated fenestration and field-fabricated exterior doors may be installed only if the documentation has demonstrated compliance with the Energy Code.

For field-fabricated fenestration, the U-factor and SHGC default values can be found in Table 3-12 and Table 3-13, respectively, below. Values are determined by frame type, fenestration type, and glazing composition.

Exterior doors with glazing for 25 percent or more of the door area are treated as fenestration products and must meet all requirements and ratings associated with fenestration. When a door has glazing of less than 25 percent the door area, the portion of the door with fenestration must be treated as part of the envelope and the fenestration independent of the remainder of the door area.

The field inspector is responsible for ensuring field-fabricated fenestration meets the specific U-factor, SHGC, and VT, as listed on the NRCC-ENV-E. Thermal break values do not apply to field-fabricated fenestration products.

Table 3-12: Default Fenestration Product U-Factors

FRAME	PRODUCT TYPE	SINGLE PANE [3, 4]	DOUBLE PANE [1, 3, 4]	GLASS BLOCK [2,3]
Metal	Operable	1.28	0.79	0.87
	Fixed	1.19	0.71	0.72
	Greenhouse/garden window	2.26	1.40	N.A.
	Doors	1.25	0.77	N.A.
	Skylight	1.98	1.30	N.A.
Metal, Thermal Break	Operable	N.A.	0.66	N.A.
	Fixed	N.A.	0.55	N.A.
	Greenhouse/garden window	N.A.	1.12	N.A.
	Doors	N.A.	0.59	N.A.
	Skylight	N.A.	1.11	N.A.
Nonmetal	Operable	0.99	0.58	0.60
	Fixed	1.04	0.55	0.57
	Doors	0.99	0.53	N.A.
	Greenhouse/garden windows	1.94	1.06	N.A.
	Skylight	1.47	0.84	N.A.

1. For all dual-glazed fenestration products, adjust the listed U-factors as follows:
   a. Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide.
   b. Add 0.05 to any product with true divided lite (dividers through the panes).
2. Translucent or transparent panels shall use glass block values when not rated by NFRC 100.
3. Visible transmittance (VT) shall be calculated by using Reference Nonresidential Appendix NA6.
4. Windows with window film applied that is not rated by NFRC 100 shall use the default values from this table.

Table 110.6-A of the Energy Code

Table 3-13: Default Solar Heat Gain Coefficient (SHGC)

FRAME TYPE	PRODUCT	GLAZING	FENESTRATION PRODUCT SHGC		
			SINGLE PANE[2,3]	DOUBLE PANE[2,3]	GLASS BLOCK[1,2]
Metal	Operable	Clear	0.80	0.70	0.70
	Fixed	Clear	0.83	0.73	0.73
	Operable	Tinted	0.67	0.59	N.A.
	Fixed	Tinted	0.68	0.60	N.A.
Metal, Thermal Break	Operable	Clear	N.A.	0.63	N.A.
	Fixed	Clear	N.A.	0.69	N.A.
	Operable	Tinted	N.A.	0.53	N.A.
	Fixed	Tinted	N.A.	0.57	N.A.
Nonmetal	Operable	Clear	0.74	0.65	0.70
	Fixed	Clear	0.76	0.67	0.67
	Operable	Tinted	0.60	0.53	N.A.
	Fixed	Tinted	0.63	0.55	N.A.
Translucent or transparent panels shall use glass block values when not rated by NFRC 200. Visible transmittance (VT) shall be calculated by using Reference Nonresidential Appendix NA6. Windows with window film applied that is not rated by NFRC 200 shall use this table's default values					

Table 110.6-B of the Energy Code

3.3.6 Determining Fenestration Performance

§110.6, TABLES 110.6-A, B

A. U-Factor

The preferred methods for determining fenestration U-factor are those in NFRC 100 for manufactured windows and for site-built fenestration. The default U-factors in Table 110.6-A must be used when a NFRC label for the U-factor is not available. The U-factors in Table 110.6-A represent the least efficient possible values, thereby encouraging designers to obtain ratings through NFRC test procedures, when they are available.

B. Solar Heat Gain Coefficient (SHGC)

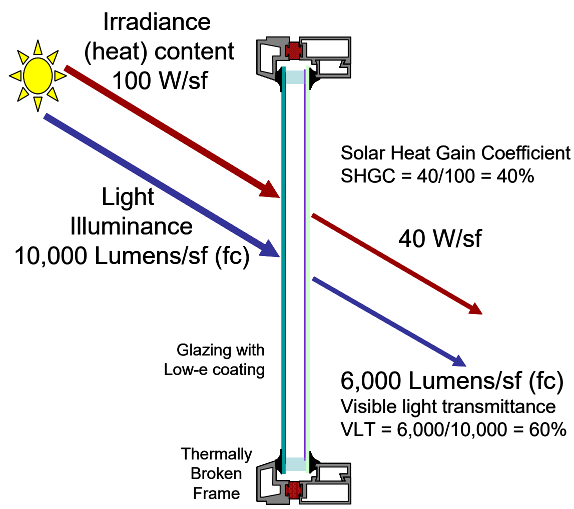
For the SHGC, the methods determining the preferred values are in NFRC 200. If they are not available, Table 110.6-B of the Energy Code must be used for default values.

C. Visible Transmittance (VT)

The visible transmittance (VT) of the fenestration shall be rated in accordance with NFRC 200 or ASTM E972. More specifically, the NFRC 200 test method is appropriate only for flat, clear glazing and does not cover curved glazing or diffusing glazing. NFRC 202 is the approved test method for rating the visible transmittance of planar diffusing glazing such as is used in fiberglass insulating fenestration. NFRC 203 is the approved test method for rating the visible transmittance of tubular skylights, also known as tubular daylighting devices (TDDs). For other types of fenestration, including dome skylights, use ASTM E972 to rate the visible transmittance.

VT is a property of glazing materials that has a varying relationship to SHGC (Figure 3-12). The ideal glazing material for most hot climates would have a high VT and a low SHGC. Such a glazing material allows solar radiation in the visible spectrum to pass while blocking radiation in the infrared and ultraviolet spectrums. Materials that have this quality are labeled “spectrally selective” and have a VT that is up to 2.2 times the SHGC.

Figure 3-14: Solar Heat Gain Coefficient and Visible Transmittance



Source: California Energy Commission

3.3.7 Air Leakage

§110.6(a)1, §110.7

Manufactured and site-built fenestration such as doors and windows must be tested and shown to have infiltration rates not exceeding the values shown in Table 3-15. For field-fabricated products or exterior doors, the Energy Code requires that the unit be caulked, gasketed, weather stripped, or otherwise sealed. Unframed glass doors and fire doors are the two exceptions to these air leakage requirements.

Table 3-15: Maximum Air Infiltration Rates (§110.6(a)1)

Class	Type	Rate
Windows (cfm/ft²) of window area	All	0.3
Residential Doors (cfm/ft²) of door area	Swinging, Sliding	0.3
All Other Doors (cfm/ft²) of door area	Sliding, Swinging (single door)	0.3
	Swinging (double door)	1.0

Source: California Energy Commission

Example 3-12

Question:

A 150,000 ft² big box retail store has 800 ft² of site-built vertical fenestration at the entrance. An operable double-pane aluminum storefront framing system is used without a thermal break. What are the acceptable methods for determining the fenestration U-factor and SHGC? What are the labeling requirements assuming a center of glass U-factor of 0.50 and SHGC of 0.70 and a center glass visible transmittance of 0.75?

Answer:

For site-built vertical fenestration being used in newly constructed buildings one of the following methods may be used:

1. Rate the fenestration using the component modeling approach (CMA), which will yield the most efficient values possible.
2. Select from default Tables 110.6-A and 110.6-B of the Energy Code. From these tables, the U-factor is 0.79 and the SHGC is 0.70. The NRCC-ENV-E should be completed for each fenestration product. Or the responsible party may attach a default temporary label to each fenestration unit throughout the building.

3.3.8 Vertical Fenestration (Windows and Doors)

3.3.8.1 Prescriptive Requirements

§140.3(a)5

There are four aspects of the envelope component approach for windows:

1. Maximum total area plus west-facing.
2. Maximum U-factor.
3. Maximum relative solar heat gain coefficient (RSHGC).
4. Minimum visible transmittance (VT).

Conditioned greenhouses are excepted from the requirements of 140.3(a)5 and the requirements of Section 120.6(h)5 apply.

A. Window Area

§140.3(a)5.A.

In the prescriptive approach, the total window area may not exceed 40 percent of the gross wall area (encompassing total conditioned space) for the building. Likewise, the west-facing window area may not exceed 40 percent of the west gross wall area (encompassing total conditioned space for the building). This maximum area requirement will affect those buildings with very large glass areas, such as high-rise offices, automobile showrooms, or airport terminals.

The maximum area may be determined by multiplying the length of the display perimeter by 6 feet in height and use the larger of the product of that multiplication or 40 percent of gross exterior wall area.

Display perimeter is the length of an exterior wall in a Group B; Group F, Division 1; or Group M occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk. This generally refers to retail display windows, although other occupancies such as offices can also have a display perimeter. Public sidewalks are accessible to the public at large (no obstructions, limits to access, or intervening nonpublic spaces). Demising walls are not counted as part of the display perimeter.

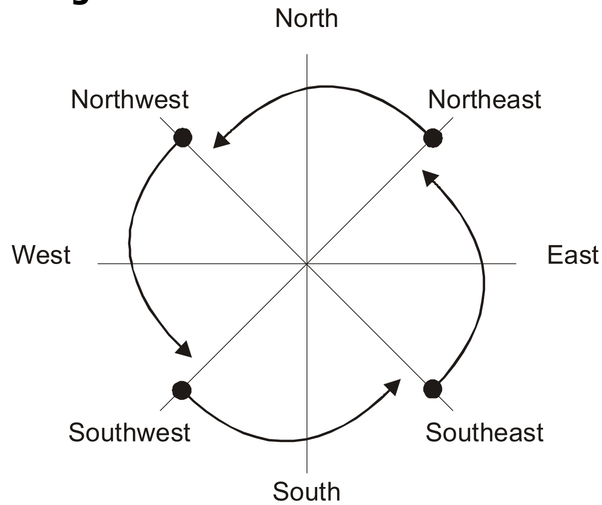
Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the prescriptive U-factor requirements for the climate zone.

Window area is generally taken from the rough opening dimensions. To the extent this opening is slightly larger than the frame, the rough opening area will be slightly larger than the formally defined window area.

Glazed doors use the rough opening area, except where the door glass area is less than 25 percent of the door, in which case the glazing area may be either the entire door area or the glass area plus 2 inches added to all four sides of the glass (to represent the "window frame") for a window in a door. Calculate the window area from the rough opening dimensions and divide by the gross exterior wall area, which does not include demising walls.

The orientation can be determined from an accurate site plan. Any orientation within 45 degrees of true north, east, south, or west will be assigned to that orientation. Figure 3-13 demonstrates how surface orientations are determined and what to do if the surface is oriented exactly at 45 degrees of a cardinal orientation. For example, an east-facing surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

Figure 3-13: Four Surface Orientations



B. Window U-Factor

§140.3(a)5B, TABLES 140.3-B,C

C. Fenestration products must meet the prescriptively required maximum U-factor criteria in Tables 140.3-B and 140.3-C of the Energy Code for each climate zone. Most NFRC-rated multi-glazed windows with a low-e coating and a thermally broken frame will comply with the U-factor criterion. See NFRC's Certified Product Directory database, or use Equation NA6-1 found in Reference Appendices, Nonresidential Appendix NA6. SHGC and Shading Factor

§140.3(a)5C

Relative solar heat gain (RSHGC) allows for an external shading correction. It is calculated by multiplying the SHGC of the fenestration product by a shading factor (SHF). If shading does not exist, then the shading factor is 1.0. Relative solar heat gain is applicable only when using the prescriptive compliance approach. Tables 140.3-B and 140.3-C specify the maximum area-weighted average RSHGC, excluding the effects of interior shading.

Shading factors depend upon the projection factor (PF) from Equation 140.3-C which is the ratio of the projection (P) and the spacing (s). These dimensions are measured from the vertical and horizontal planes passing through the bottom edge of the window glazing for overhangs or the slat below for horizontal slats, as shown in Figures 3-14. A shading factor may be used if the shading extends beyond both sides of the window jamb a distance equal to the overhang projection (§140.3(a)5Cii), or if the entire horizontal slat assembly is completely contained within a window setback. If the shading is continuous along the side of a building, this restriction will usually be met. If there are shades for individual windows, each must be shown to comply.

Figure 3-14a: Overhang Dimensions

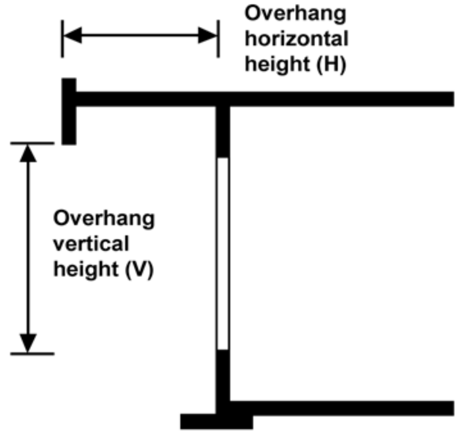
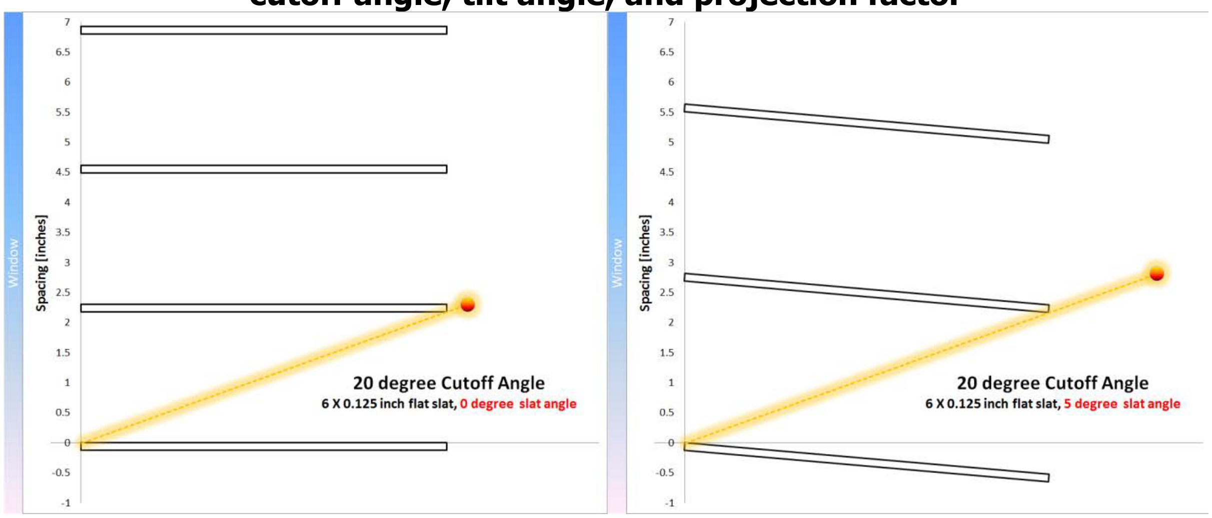


Figure 3-14b: Exterior horizontal slat – cutoff angle, tilt angle, and projection factor



Equation 3-1 – Relative Solar Heat Gain Coefficient

$$RSHGC = SHGC_{win} \times SHF = SHGC_{win}[1 + a(e^{-PF} - 1)(\sin(b \times Az) - c)]$$

Where:

RSHGC	=	The Relative Solar Heat Gain
$SHGC_{win}$	=	The NFRC SHGC of the window
SHF	=	The shading factor of the window
Az	=	The azimuth (orientation) of the window in degrees clockwise from north
PF	=	P/s, The projection factor of the exterior shade

	a	b	c
Overhang	0.150	0.130	5.67
Horizontal Slat	0.144	0.133	5.13

Figures 3-15 illustrates the benefits of shading factors of the various projection factors as a function of azimuth (orientation) for overhangs and as a function of tilt angle for horizontal slats. The chosen projection factors correspond to cutoff angles every 15 degrees. The graph shows that savings can be significant and that benefits increase as windows face more towards a southerly direction and also increase as overhangs or slats project more (i.e., have a higher projection factor).

Figure 3-15a: Graph of Shading Factors for Overhangs

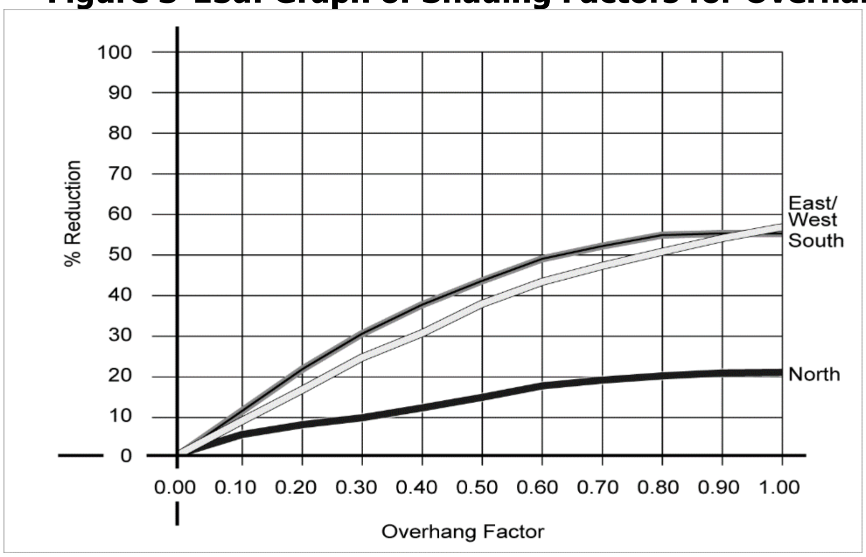
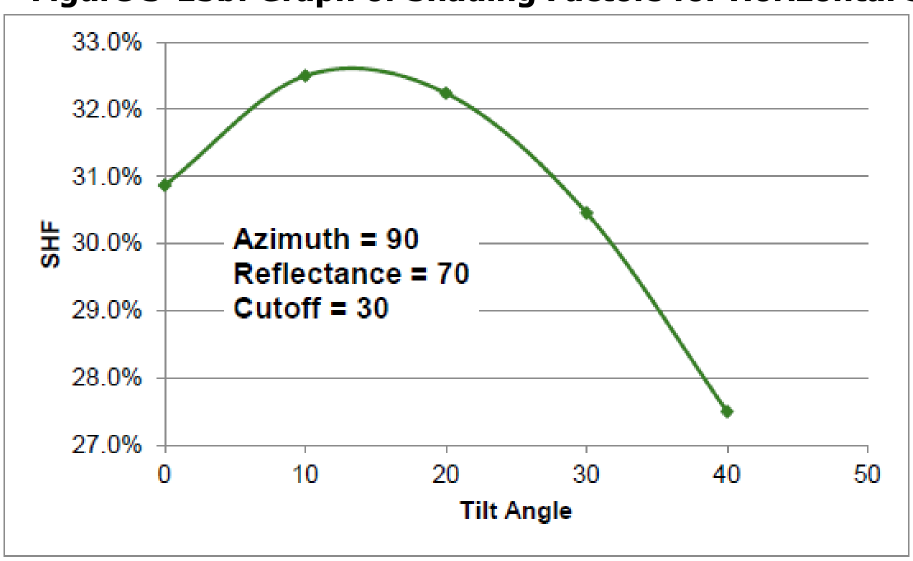


Figure 3-15b: Graph of Shading Factors for Horizontal Slats



Example 3-13

Question:

An window facing due east has glass with a solar heat gain coefficient of 0.71. It has a fixed overhanging eave that extends 3 feet out from the plane of the glass (P = 3) and is 6 feet above the bottom of the glass (s = 6). The overhang extends more than 3 feet beyond each side of the glass, and the top of the window is less than 2 feet vertically below the overhang. What is the RSHGC for this window?

Answer:

First, calculate the projection factor as P/s. This value is 3 / 6 = 0.50. Next, calculate the shading factor using the 90 degrees azimuth of the window, this value is 0.60. Finally, multiply it by the solar heat gain coefficient to obtain the RSHGC: 0.62 x 0.71 = 0.44.

D. Visible Light Transmittance (VT)

§140.3(a)5D

The prescriptive requirements of Tables 140.3-B and 140.3-C (Table 3-16) of the Energy Code prescribes specific VT values for all climate zones and glass types. The visible light transmittance is used in the performance method in the calculation of the interior illumination levels and lighting energy savings due to daylight controls. The performance method is discussed in more detail in Chapter 5.

Fenestration must meet the climate zone-specific prescriptive requirement of having an area-weighted average VT of 0.42 or greater for fixed windows, 0.32 or greater for operable windows, 0.46 or greater for curtain walls and 0.17 or greater for glazed doors. Products with spectrally selective "low-e" coatings (also known as single, double or triple silver low-e) are available to meet this requirement.

A combination of high VT glazing in the upper part of a window (clerestory) and lower VT glazing at the lower part of the window (view window) can be used, as long as the area-weighted average meets the prescriptive requirement. This allows daylight to enter the space through the high VT glazing making a better daylighting design.

The Energy Code also allows a slight variance if the window-to-wall ratio (WWR) is greater than 40 percent. For this case, assume 0.40 for the WWR in the equation below or the glazing can comply with the prescriptive requirements if the area-weighted average VT meets the following minimum requirement:

Equation 3-3 *– Visible Light Transmittance*

$$VT \geq 0.11 / WWR$$

Where:

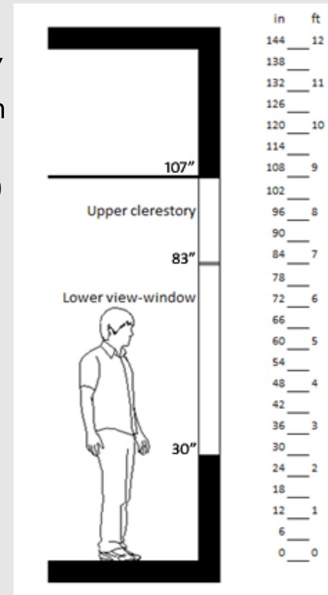
VT = the visible transmittance of the framed window

WWR = the gross window-to-wall ratio

The average VT requirements apply separately to chromatic (dynamic or color changing) glazing and nonchromatic glazing. For chromatic glazing, higher ranges of VT can be used to meet the prescriptive requirements. All glazing that is not chromatic must separately meet the area-weighted VT prescriptive requirements.

Example 3-14

Question:



A space has a gross window-to-wall ratio of 30 percent and has a fixed window with a sill height of 2'6" (30") and a head height of 8'11" (107"), which runs 10' wide (120"). The window has a break at 6'11" (83") such that the upper portion or clerestory portion of the window is 2' (24") tall and can have a glazing different from that in the lower portion (view window). Can a designer use 0.30 VT glazing in the view window?

Answer:

Use the formula VT ≥ 0.11 / WWR, to determines the minimum area weighted average VT for this space,

VT ≥ 0.11 / 0.3 = 0.367. The area weighted minimum VT we need for this window is 0.367.

(View window Area x View window VT) + (Clerestory Area x Clerestory VT) / Total Window Area = 0.367

In this case:

Clerestory area = 24" height x 120" width = 2,880 sq.in

View window area = (83" - 30") height x 120" width = 6,360 sq.in.

Using a 0.30 VT glazing in the view window then View window VT = 0.30

Total window area = (107" - 30") height x 120" width = 9,240 sq.in.

Solve the equation for Clerestory VT: Clerestory VT = 0.515

(6360 x 0.367) + (2880 x VT_{CL})/9240

To use a 0.3 VT glazing in the view window, the designer must use a 0.515 VT window in the clerestory.

Example 3-15

Question:

A designer is using a U-factor of 0.57 for compliance with a curtain wall system. The glazing system uses two lites of 1/4 in (6mm) glass with a low-e= 0.1 coating on the second surface. The air gap is 1/2 inch (12 mm). A standard metal frame is proposed for the curtain wall system. Is 0.57 a reasonable U-factor for compliance, and can it reasonably be achieved by the glazing contractor through the NFRC process for site-built fenestration?

Answer:

No. If this is is a newly constructed building and there is no NFRC rating, then the default U-factor must be used for this glazing combination from Table 110.6-A of the Energy Code must be used. In this example the U-factor would be 0.71.

However, if this is part of an alteration then the design U-factor may be calculated using the default U-factor equation (Equation NA6-1) in the Reference Appendices, Nonresidential Appendix, NA6. Assuming a center of glass U-factor of 0.32, then the calculated U-factor would be 0.59.

3.3.9 Compliance Options

A. Dynamic Glazing – Chromatic Glazing

Chromatic-type fenestration has the ability to change performance properties (U-factor, SHGC, and VT). The occupant can manually or automatically control his or her environment by tinting or darkening a window with the flip of a switch or by raising/lowering a shade positioned between panes of glass. Some windows and doors change the performance automatically in response to a control or environmental signal. These smart windows provide a variety of benefits, including reduced energy costs due to controlled daylighting and unwanted heat gain or heat loss.

Look for NFRC Dynamic Glazing Labels to compare and contrast the energy performance for these products. See Figure 3-17. The unique rating identifiers help consumers understand the dynamics of the product and allow comparison with other similar fenestration products. If the product can operate at intermediate states, a dual directional arrow, **(↔),** with the word *variable* underneath will appear on the label. Some dynamic glazing is able to adjust to intermediate states, allowing for a performance level between the endpoints. The low value rating is displayed to the left (in the closed position), and the high value rating is displayed to the right (in the open position). This lets the consumer know at a glance the best and worst case performance of the product and what the default or de-energized performance level will be.

Figure 3-17: Dynamic Glazing NFRC Label

Source: NFRC

To receive chromatic glazing credit, the following must be met:

1. Optional prescriptive U-factor and SHGC from Tables 140.3-B and 140.3-C
2. Performance approach compliance gives maximum credit allowance for best rating
3. Automatic controls to receive best rating values or
4. NFRC Dynamic Glazing Compliance Label is required. Otherwise, default to Table 110.6-A and 110.6-B values.

B. Window Films

Window films are made of mostly polyester substrate that is durable, tough, and highly flexible. It absorbs little moisture and has both high and low temperature resistances. Polyester film offers clarity and can be pretreated to accept different types of coatings for energy control and long-term performance. Window films are made with a special scratch-resistant coating on one side and with a mounting adhesive layer on the other side. The adhesive is normally applied to the interior surface (room side) of the glass unless a film is specifically designed to go on the exterior window surface. Film can be metalized and easily laminated to other layers of polyester film.

There are three basic categories of window films:

1. **Clear** (nonreflective) films are used as security films and to reduce ultraviolet (UV) light, which contributes to fading. These are not normally used for solar control or energy savings.
2. **Tinted or dyed** (nonreflective) films reduce both heat and light transmission, mostly through increased absorptance and can be used in applications where the primary benefit desired is glare control with energy savings secondary.
3. **Metalized** (reflective) films can be metalized though vacuum coating, sputtering, or reactive deposition and may be clear or colored. Metalized films are preferred for energy-saving applications since they reduce transmission primarily through reflectance and are manufactured to selectively reflect heat more than visible light through various combinations of metals.

Look for the NFRC-certified attachment ratings energy-performance label, which helps consumers understand the contrast in energy performance of window films. An example of a window film energy performance label is shown on Figure 3-18.

Window Film Compliance

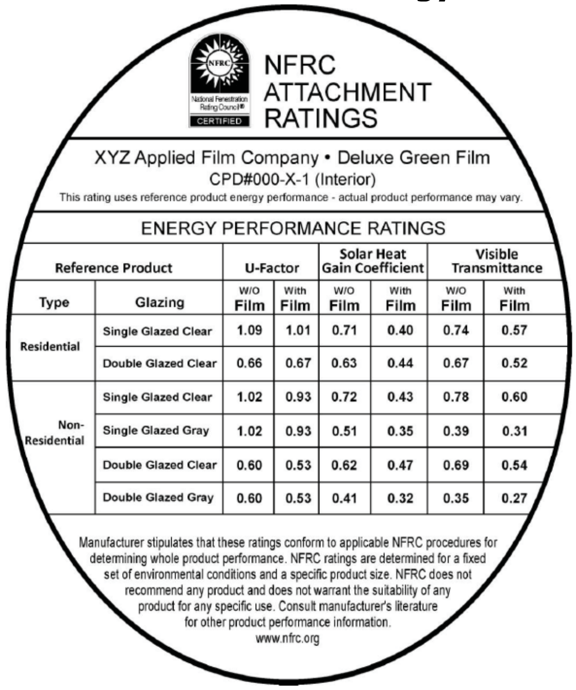
To receive window film credit, the following must be met:

1. The performance approach must be used.
2. Use only the alteration to existing building compliance method.

a. The NFRC window film energy performance label is required for each film; otherwise, use the Default Table 110.6-A and 110.6-B values.

b. Window films shall have a 15-year or longer warranty.

Figure 3-18: Window Film Energy Performance Label



NFRC ATTACHMENT RATINGS

National Fenestration Rating Council® CERTIFIED

XYZ Applied Film Company • Deluxe Green Film
CPD#000-X-1 (Interior)
This rating uses reference product energy performance - actual product performance may vary.

ENERGY PERFORMANCE RATINGS

Reference Product		U-Factor		Solar Heat Gain Coefficient		Visible Transmittance	
Type	Glazing	W/O Film	With Film	W/O Film	With Film	W/O Film	With Film
Residential	Single Glazed Clear	1.09	1.01	0.71	0.40	0.74	0.57
	Double Glazed Clear	0.66	0.67	0.63	0.44	0.67	0.52
Non-Residential	Single Glazed Clear	1.02	0.93	0.72	0.43	0.78	0.60
	Single Glazed Gray	1.02	0.93	0.51	0.35	0.39	0.31
	Double Glazed Clear	0.60	0.53	0.62	0.47	0.69	0.54
	Double Glazed Gray	0.60	0.53	0.41	0.32	0.35	0.27

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information.
www.nfrc.org

Source: NFRC

3.3.10 Skylights

Skylights can be either flush-mounted or curb-mounted into a roof system. To ensure water flows around them, skylights are often mounted on curbs set above the roof plane. These curbs, rising 6 to 12 inches above the roof, create additional heat loss surfaces.

3.3.10.1 Skylight Mandatory Requirements

§10-111, §110.6, §110.7

Skylights must meet all mandatory requirements for fenestration in §10-111, §110.6 and §110.7. Either the prescriptive or performance approach may be used.

When skylights are specified, the designer must show the skylit daylight zones on the building plans. There are mandatory requirements for lighting controls related to daylighting. See Section 3.3.3. Automatic daylighting controls are required when the installed power in the daylit zones of a room is greater than 120W. See Chapter 5 of this manual for a detailed discussion of the daylight zones.

3.3.10.2 Skylight Prescriptive Requirements

§140.3(a)6

There are four aspects of the prescriptive envelope approach for skylights:

1. Maximum total area.
2. Maximum U-factor.
3. Maximum solar heat gain coefficient (SHGC).
4. Minimum visible transmittance (VT).

Table 3-16: Skylight Requirements (Area-Weighted Performance Rating) For all Climate Zones

		Glass, Curb Mounted	Glass, Deck-Mounted	Plastic, Curb-Mounted	Tubular Daylighting Devices (TDDs)
Nonresidential	U-factor	0.58	0.46	0.88	0.88
Nonresidential	SHGC	0.25	0.25	NR	NR
Nonresidential	VT	0.49	0.49	0.64	0.38
Nonresidential	Maximum SRR%	5%	5%	5%	5%
Hotel/Motel Buildings	U-factor	0.58	0.46	0.88	
Hotel/Motel Buildings	SHGC	0.25	0.25	NR	
Hotel/Motel Buildings	VT	0.49	0.49	0.64	
Hotel/Motel Buildings	Maximum SRR%	5%	5%	5%	5%

Excerpt from Energy Code, Tables 140.3-B and 140.3-C, Skylight Roof Ratio, SRR

A. Skylight Area

§140.3(a)6A

Skylight area is defined in Reference Appendices, Joint Appendix JA1 as the area of the rough opening of a skylight. The area limit for skylights is 5 percent of the gross exterior roof area, called the skylight roof ratio (SRR). The limit increases to 10 percent for buildings with an atrium more than 55 feet high. The 55-foot height is the threshold at which the California Building Code requires a mechanical smoke-control system for atriums (CBC Sec. 909). This means that the 10 percent SRR is not allowed for atriums unless they also meet the smoke control requirement.

Site-built monumental or architectural skylights equipped with integral built-in or site-built curbs (not part of the roof construction) are often used for atrium roofs, malls, and other applications that need large skylights. In these cases, the skylight area is the surface area of the glazing and frame/curb, *not the area of the rough-framed opening*. Regardless of the geometry of the skylight (flat pyramid, bubble, barrel vault, or other three-dimensional shape), what matters is the anticipated heat exchanged through the glazing area. For special cases such as clerestory, rooftop monitor or tubular skylights, see Chapter 5.

§140.3(c)4 requires that the skylight area be at least 3 percent of the floor area (not accounting for obstructions), or that the total of the skylight area multiplied by the area-weighted average visible transmittance of the skylights be at least 1.5 percent of the floor area (not accounting for obstructions). This assures that enough light reaches the skylit spaces. The visual transmittance option acknowledges that more skylight area is not needed for buildings with highly transmitting skylights. For example, if plastic skylights are installed with the prescriptive minimum transmittance of 0.64, the maximum ratio of skylight area to floor area within 0.7 times the ceiling height of skylights is 2.3 percent.

B. Skylight U-Factor

§140.3(a)6B

The U-factor for skylights is an inclusive measurement of its heat losses, and includes heat losses through the glazing, the frame, and the integral curb (when one exists). If an NFRC rating does not exist, such as for projecting plastic skylights, the designer can use default fenestration U-factors found in Table 110.6-A of the Energy Code.

For skylights, the U-factor criteria depend on whether the skylight glazing material is plastic or glass, and whether the skylight is curb-mounted, noting that plastic skylights are assumed to be mounted on a curb. These criteria are shown in Tables 140.3-B, C, and D. (Table 3-16)

C. Skylight SHGC

§140.3(a)6C

Skylights are regulated for SHGC rather than RSHGC because skylights cannot have overhangs. The SHGC criteria vary with the SRR, and the criteria can be found in Tables 140.3-B, C, and D (Table 3-17). The designer can use default SHGC values in Table 110.6-B of the Energy Code or can use the Reference Appendices, Nonresidential Appendix NA6 if all site-built fenestration (skylights and vertical fenestration) is less than 200 ft².

D. Visible Transmittance (VT)

§140.3(a)6D

Skylights shall have an area-weighted average visible transmittance (VT) of no less than the value required by Tables 140.3-B, C, and D (Table 3-16). There are exceptions for chromogenic glazing.

E. Daylighting

Appropriately sized skylight systems can dramatically reduce the lighting energy consumption of a building when combined with appropriate daylighting controls. Daylighting control requirements under skylights are discussed in Chapter 5.

Mandatory Daylighting Controls

§130.1(d)

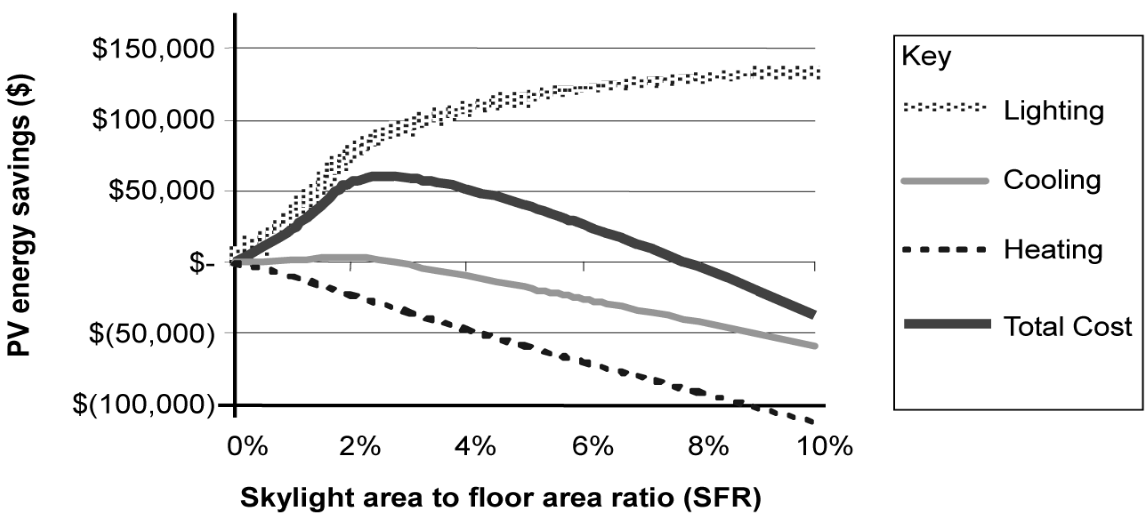
Electric lighting in skylight daylit zones shall meet the mandatory control requirements in §130.1(d). Obstructions are ignored for evaluating the architectural area served by skylights. For controlling lighting, consider the area shaded that is behind permanent obstructions that are greater than half the ceiling height. Those luminaires behind tall obstructions are not part of the skylit daylit area and not controlled by automatic daylighting controls.

Minimum Daylighting Prescriptive Requirements in Large Enclosed Spaces

§140.3(c)

Sizing is important; since too little skylight area has insufficient light available to turn off electric lighting; where too much skylight area, solar gains and heat losses through skylights negate the lighting savings by adding heating and cooling loads.

Figure 3-19: Present Value Savings of Skylight 50,000 ft² Warehouse in Climate Zone 12



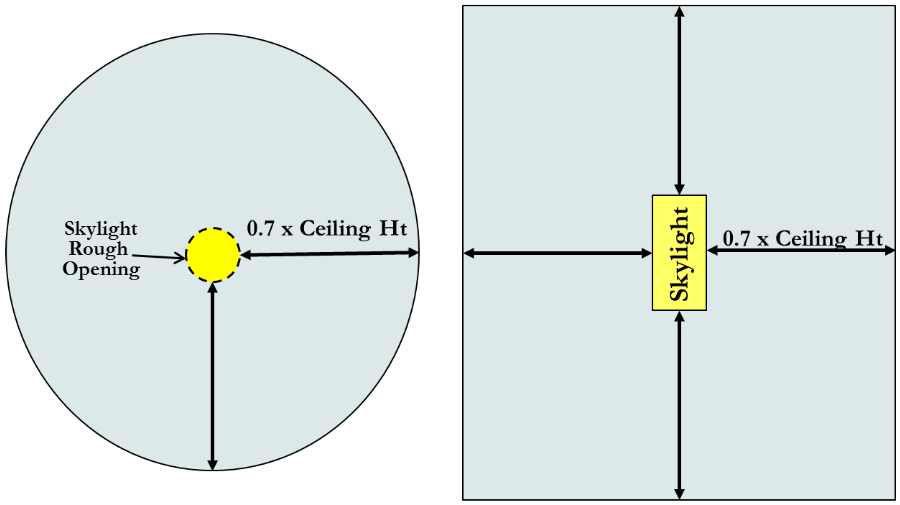
Skylights and automatic daylighting controls are most cost-effective in large open spaces and are prescriptively required in enclosed spaces (rooms):

- Larger than 5,000 ft².
- Directly under a roof.
- Ceiling heights greater than 15 ft.
- Lighting power densities greater than 0.3 W/ft².

The Energy Code requires that at least 75 percent of the floor area be within one or more of the following:

1. A skylit daylit zone, an area in plain view that is directly under a skylight or within 0.7 times the average ceiling height in each direction from the edges of the rough opening of the skylight (see Figure 3-20), or
2. A primary sidelit, daylit zone, an area in plain view that is directly adjacent to vertical glazing, one window head height deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window based on §130.1(d).

Figure 3-20: Area Within 0.7 Times Ceiling Height of Rough Opening of Circular Skylight and Rectangular Skylight

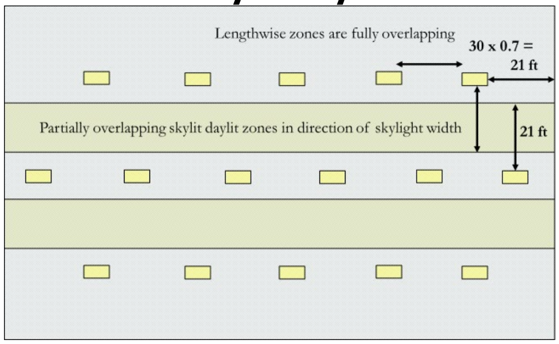


The shape of the skylit daylit zone will be similar in shape to the rough opening of the skylight (Figure 3-20).

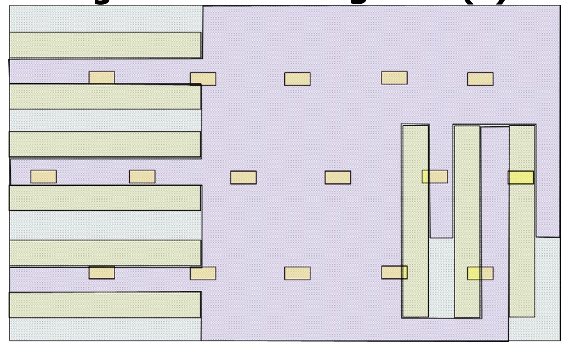
Examples: If the skylight is circular, the area that is within a horizontal distance 0.7 times the average ceiling height from the edge of the rough opening, is also a circle, with the radius of the circle being the radius of the skylight + 0.7 x the ceiling height.

If the skylight is rectangular, the zone is rectangular, with the edges increased in each direction by 0.7 times the ceiling height.

Figure 3-21: Comparison of Skylit Area for Calculating Minimum Skylit Area and the Skylit Daylit Zone for Controlling Luminaires in §130.1(d)



a) Entire space is within 0.7 x ceiling height of skylights for meeting minimum daylit area (§140.3(c))



b) Skylit daylit zone (§130.1(d)) for controlling luminaires is limited by racks blocking daylight

The specifications for daylighting controls in §130.1(d) describe which luminaires must be controlled, and consider the daylight obstructing effects of tall racks, shelves, and partitions taller than one-half the distance from the floor to the bottom of the skylight when determining if daylight will reach a given space. As shown in Figure 3-21, it is considerably easier to calculate.

(a) The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights.

Versus

(b) The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights, minus any area on a plan beyond a permanent obstruction that is taller than the following: A permanent obstruction that is taller than one-half the distance from the floor to the bottom of the skylight.

(a) is required to be calculated to comply with minimum skylight area requirements of §140.3(c), and (b), is required to comply with the automatic daylighting control requirements of §130.1(d) (essentially, to ensure that daylighting controls are not installed where they would not be effective).

In §130.1(d), the skylit daylit areas are required to be drawn on the plans, and any general lighting luminaires that are in the daylit zones must be separately controlled by automatic daylighting controls. (See the daylighting requirements in Chapter 5 Lighting).

Two exemptions from §140.3(c) include:

1. *Auditoriums, controlled environment horticulture spaces, churches, museums, and movie theaters due to the demanding lighting control needs.*
2. *Refrigerated warehouses to minimize heat gains.*

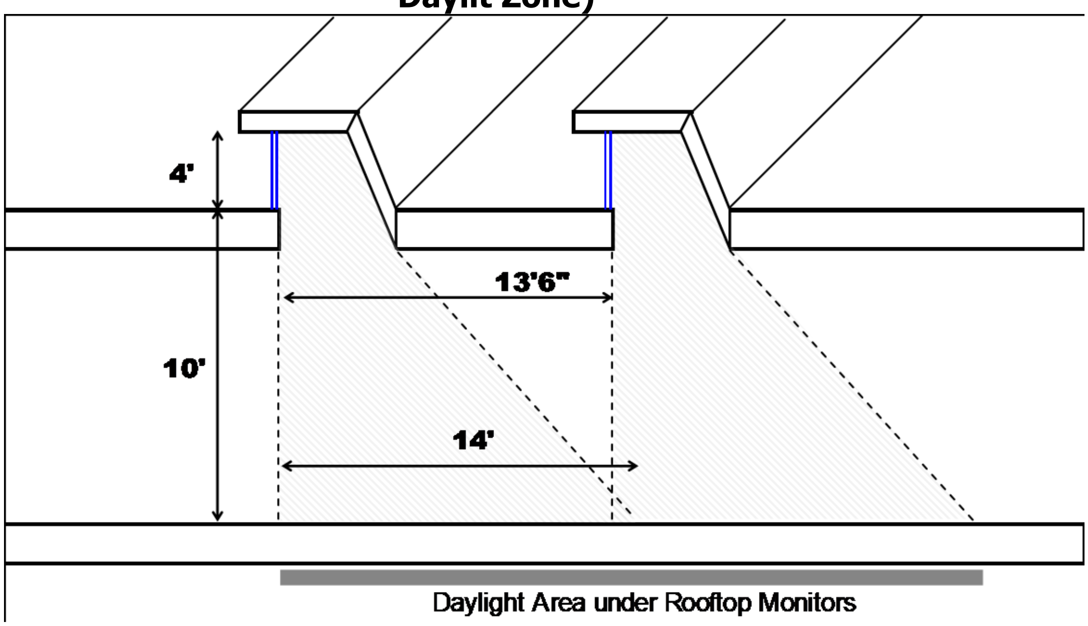
Since skylights paired with daylighting controls can significantly reduce energy demands from lighting, they are mandatory on all nonresidential occupancies that meet the above criteria *whether the space is conditioned or unconditioned*. Further information can be found in Section 3.3.3.1.

For large buildings with high ceilings, skylighting 75 percent of the floor area can be achieved by evenly spacing skylights across the roof of the building. As a general rule, a space can be fully skylighted by having skylights spaced so that the edges of the skylights are not further than 1.4 times the ceiling height apart. For example, in a space having a ceiling height of 20 feet, the space can be fully skylighted if the edges of skylights are no more than 28 feet apart.

F. Rooftop Monitors

Rooftop monitors are considered vertical fenestration, and the daylight area next to them is the same as the daylit area next to other vertical fenestration. The daylit area is from the inward facing plane of the fenestration one window head height and in the direction parallel to the fenestration 0.5 window head heights on either side.

Figure 3-22: Daylight Area Under Rooftop Monitors (Primary Sidelit Daylit Zone)



G. Exceptions for Shading

Minimum daylighting requirements are exempted for spaces where permanent architectural features of the building, existing structures, or natural objects, block direct beam sunlight on at least half of the roof over the enclosed space for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m. This can be documented to the local building official using a variety of tools including equipment that superimposes the sun path diagram on a photograph of the sky taken at the site[4], hand calculation tools such as the sun path calculator[5], and computer-aided design software tools that automate this calculation.

3.3.10.3 Ignoring Partitions and Shelves

The rationale for ignoring the presence of partitions for specifying minimum skylight area and spacing is that the design of the envelope may be developed before there is any knowledge of the location of the partial height partitions or shelves, as is often the case for core and shell buildings. Thus, the architectural daylit zone requirement of 75 percent of the space area indicates the possibility of the architectural space being mostly daylit. By not accounting for partial ceiling height partitions and racks, the Energy Code is consistent in addressing architectural daylit areas, regardless of whether the design is core and the shell or a complete design development, including interior design. This approach does not require the addition of extra skylights or windows if racks and partial height partitions are added later.

Example 3-16

Question:

What is the maximum spacing and recommended range for skylights in a 40,000 square foot warehouse with 30-foot-tall ceiling and a roof deck?

Answer:

From the definition of *Skylit Daylit Zone* in Section 130.1(d), the maximum spacing of skylights that will result in the space being fully skylit is:

Maximum skylight spacing = 1.4 x Ceiling Height + Skylight width

Spacing skylights closer together results in more lighting uniformity and thus better lighting quality, – but costs more as more skylights are needed. However, as a first approximation, one can space the skylights 1.4 times the ceiling height. For this example, skylights can be spaced 1.4 x 30 = 42 feet. In general, the design will also be dictated by the size of roof decking materials (such as 4’ by 8’ plywood decking) and the spacing of roof purlins so the edge of the skylights line up with roof purlins. For this example, staff assumes that roof deck material is 4-foot by 8-foot and skylights are spaced on 40-foot centers.

Each skylight is serving a 40-foot by 40-foot area of 1,600 sf. A standard skylight size for warehouses is

often 4-foot by 8-foot (so it displaces one piece of roof decking). The ratio of skylight area to daylit area is 2 percent (32/1600 = 0.02). Assuming this is a plastic skylight and it has a minimally compliant visible light transmittance of 0.64, the product of skylight transmittance and skylight area to daylit area ratio is

(0.64)(32/1,600) = 0.013 = 1.3%

4 Resource noted for information only, not intended as an endorsement: http://www.solarpathfinder.com/

5 Resource noted for information only, not intended to be an endorsement https://www.pilkington.com/resources/pilkingtonsunanglecalculatormanual.pdf

This is a little less than the 2 percent rule of thumb described earlier for the product of skylight transmittance and skylight area to daylit area ratio. If one installed an 8-foot by 8-foot skylight (two 4-foot by 8-foot skylights) on a 40-foot spacing, it would yield a 2.6 percent product of skylight transmittance and skylight area to daylit area ratio and provide sufficient daylight. With 64 square feet of skylight area for each 1,600 square feet of roof area, the skylight-to-roof area ratio (SRR) is 4 percent, which is less than the maximum SRR of 5 percent allowed by Section 140.3(a) and thus complies with the maximum skylight requirement.

An alternate (and improved) approach would be to space 4-foot x 8-foot skylights closer together, which would provide more uniform daylight distribution in the space and could more closely approach the desired minimum VT skylight area product. A 32-foot center-to-center spacing of skylights results in (32 x 32) = 1,024 square feet of daylit area per skylight. By taking the product of the skylight VT and the skylight area and dividing by 0.02 (the desired ratio), it yields the approximate area the skylight should serve. In this case, with a VT of 0.64 and a skylight area of 32 square feet, each skylight should serve around:

$$(0.64 \times 32 / 0.02) = 1{,}024 \text{ square feet.}$$

For a minimally compliant 4 ft by 8 ft plastic skylight with a visible light transmittance of 0.64, the product of skylight transmittance and skylight area to daylit area ratio is:

$$(0.64)(32/1{,}024) = 0.020 = 2.0 \text{ percent}$$

Energy savings can be improved than this rule of thumb approach by using a whole-building energy performance analysis tool that enhances the trade-offs among daylight, heat losses and gains, and electric lighting energy consumption.

3.3.10.4 Glazing Material and Diffusers

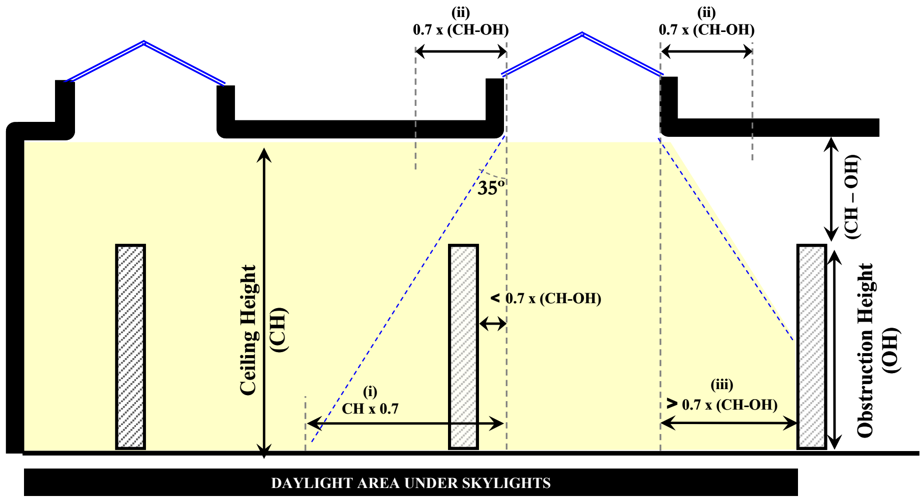
§140.3(a)6E, TABLE 140.3-B,C

Skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003 (notwithstanding its scope) or other test method approved by the Energy Commission.

When the skylights are above unconditioned spaces, there is no limitation placed on the maximum skylight area or the U-factor or SHGC. Regardless of whether the space is conditioned, the Energy Code require that the skylights diffuse and bring in enough sunlight so that, when the electric lights are turned off, the occupants have relatively uniform daylight in the space. If the space is unconditioned, single-glazed skylights will comply with the code requirements as long as the glazing or diffuser material has a haze rating greater 90 percent and the visible transmittance meets the VT requirements in Table 140.3-B or C of the Energy Code. Products that have such a rating include prismatic diffusers, laminated glass with diffusing interlayers, pigmented plastics, and so forth. This requirement assures that light is diffused over all sun angles. Any unconditioned space that later becomes conditioned must meet the newly constructed building envelope requirements. Therefore, if the space may become conditioned in the future, it is recommended that the envelope meet the conditioned envelope thermal requirements.

Other methods that result in sufficient diffusion of light over the entire year would also be acceptable in lieu of using diffusing glazing. Acceptable alternatives are baffles or reflecting surfaces that ensure direct beam light is reflected off a diffuse surface before entering the space over all sun angles encountered during a year. This alternative method of diffusion would need to be documented by the designer and approved by the code authority in your jurisdiction.

Figure 3-23: Daylit Area Under Skylights



3.3.11 Daylighting Design Power Adjustment Factors (PAFs)

Certain design features and technologies have the capacity to increase the daylighting potential of spaces. Some of these design features and technologies may be used in conjunction with automatic daylighting controls to receive PAFs from Table 140.6-A, or as a performance compliance option in the performance method.

A thorough daylighting analysis should be performed to ensure the avoidance of glare issues when including daylighting features in the design. Caution should be taken when using horizontal slats with specular reflection (e.g., polished or mirror-finished). These slats may redirect direct beam sunlight causing uncomfortable glare. This is not the only consideration when designing daylighting features. Daylighting analysis should be performed on a space-by-space, project-by-project basis.

Throughout all phases of the project, the envelope and lighting designers will need to coordinate closely to ensure that the requirements are met for their respective disciplines. Even if the envelope (e.g., horizontal slats) portion of the requirements meets all the envelope requirements, installing daylighting controls that do not meet the daylighting controls requirements will result in a loss of the PAF or performance compliance option. Chapter 5, Section 5.5.1 gives guidance on the daylighting controls requirements.

3.3.11.1 Clerestory Fenestration

§140.3(d)1

Clerestory windows may be used in conjunction with automatic daylighting controls to receive a prescriptive PAF. Clerestory windows increase the head height of windows and therefore increase the depth and width of the primary and secondary daylit zones for a space.

As with all vertical fenestration installed in a building, clerestory windows must meet the vertical fenestration requirements.

A. Qualifying Fenestration Area

Any portion of vertical fenestration area 8 feet or higher above the finished floor of a space is considered a clerestory window. Note that a rooftop monitor (see Figure 3-22) qualifies as a clerestory window.

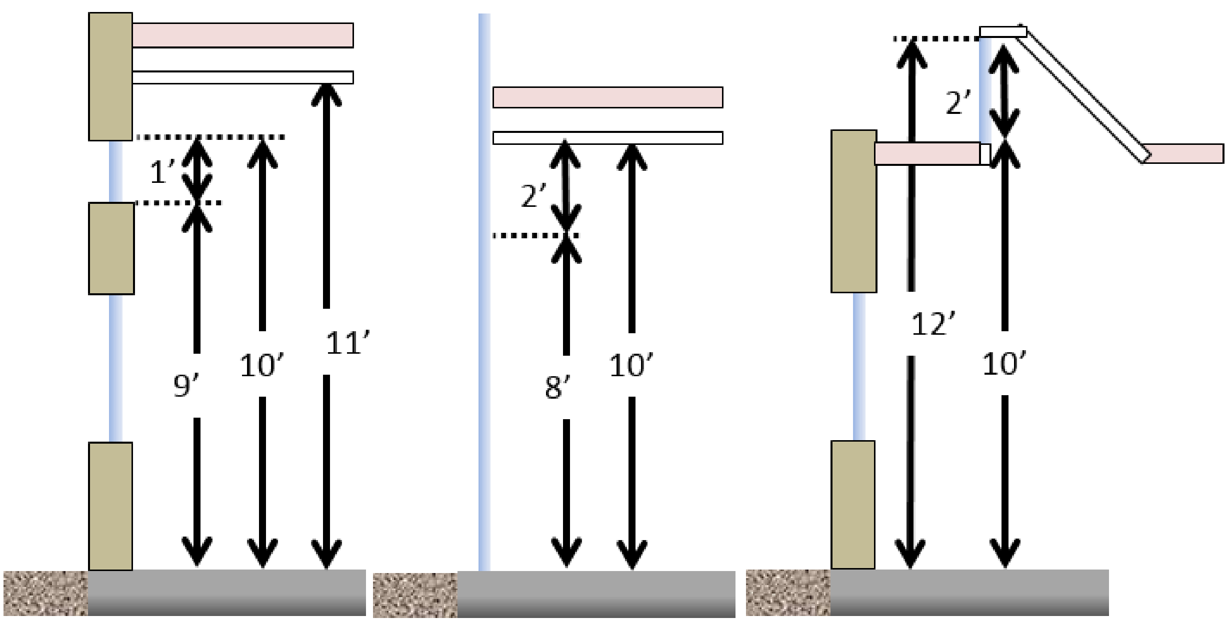
B. Orientation

For the PAF, the clerestory windows must be installed on east-, west- or south-facing facades.

C. Head Height and Window Height

For the PAF, clerestory windows must have a head height at least 10 feet above the finished floor of the space onto which the clerestory window is installed. The clerestory window height must be at least 10 percent of its head height. Examples are given in Figure 3-24.

Figure 3-24: Prescriptive PAF Clerestory Window Examples



D. Shading

Blinds or shading may not be installed at the time of inspection. However, if blinds or shading are installed at the time of inspection, then the blinds or shading which covers the clerestory window must be shown to be controlled separately from shading serving other vertical fenestration.

3.3.11.2 Interior and Exterior Horizontal Slats

§140.3(d)2

Horizontal slats on exterior or interior of windows may be used in conjunction with automatic daylighting controls to receive a prescriptive PAF or as a performance compliance option in the performance method. Exterior horizontal slats may be preferable in a design to reduce solar gains whereas interior horizontal slats may be preferable considering wind loads, thermal bridging, passive solar heating, or vandalism.

A. Adjacency and Window-to-Wall Ratio (WWR)

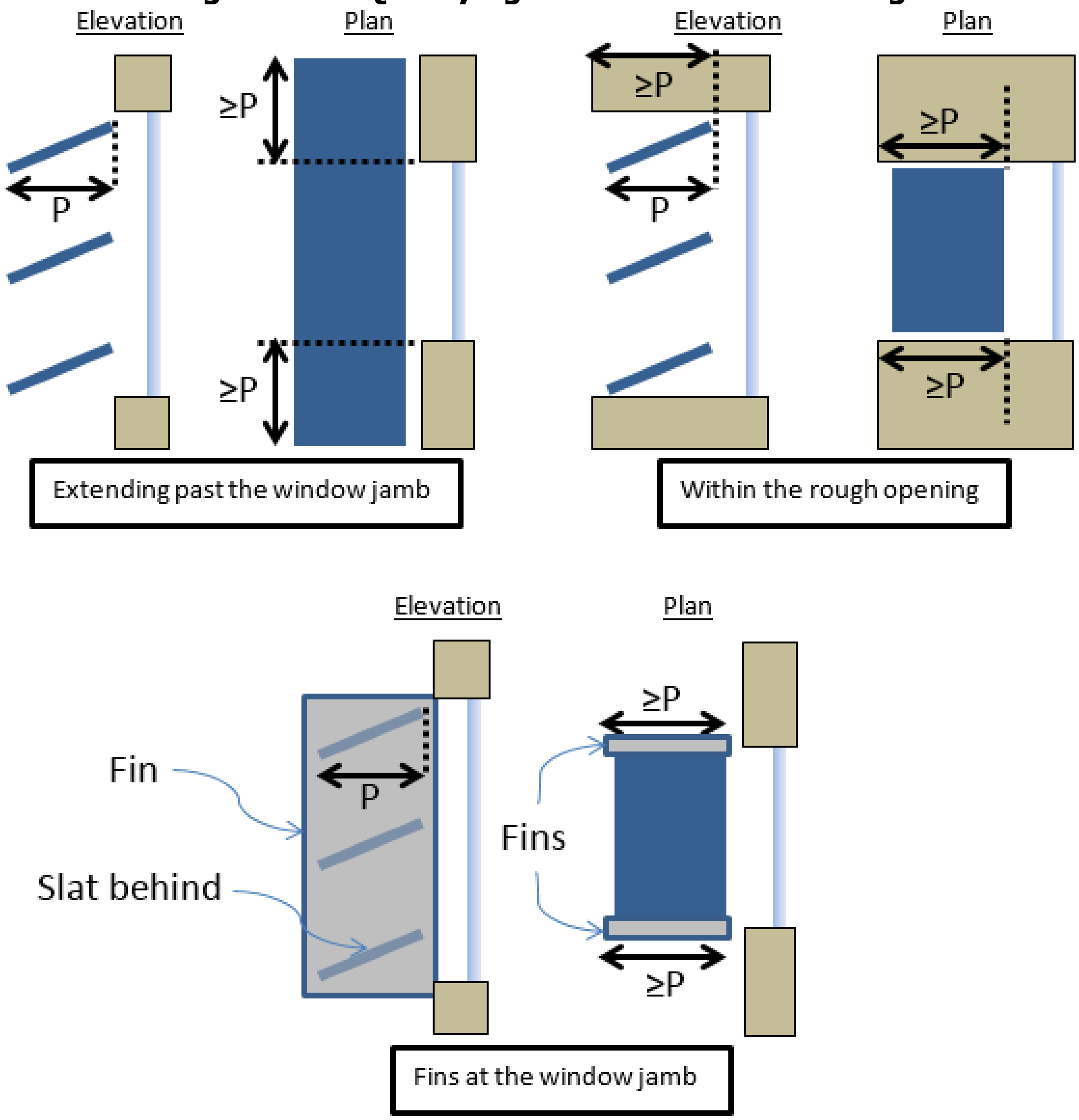
For the PAF, horizontal slats must be installed adjacent to (in front or behind) vertical fenestration. They must also extend the entire height of the window, and the WWR must be between 20 percent and 30 percent. The horizontal slats must be mounted on windows on east- and west-facing facades.

B. Side-Shading

Horizontal slats must block direct beam sunlight at their side edges. At sharp horizontal angles to the window (i.e., high and low relative azimuths), direct beam sunlight still passes through horizontal slats if they are only as wide as the window. Similar to overhangs, slats must extend on either side of the window at least as far as their horizontal projection.

Alternatively, the horizontal slats can be located entirely within the reveal for the window or have fins on either side from top to bottom. Diagrams of qualifying side-shading configurations are given in Figure 3-25.

Figure 3-25 Qualifying Horizontal Side-Shading



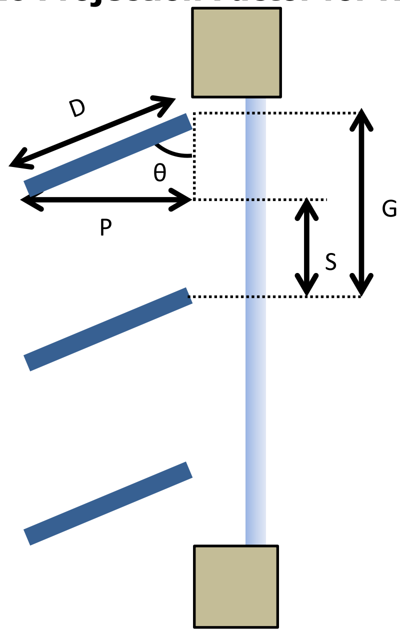
C. Projection Factor

Horizontal slats must shade direct beam sunlight from above. They may be level or slope downwards when looking out the window (i.e., exterior horizontal slats slope downwards from fenestration while interior horizontal slats slope upwards from fenestration).

Projection factor is the ratio of the effective horizontal depth to the effective vertical spacing of a shading surface.

For the PAF, the projection factor must be at least 2.0 and no greater than 3.0. The projection factor is calculated per Equation 140.3-C. Horizontal slat angle, depth, gap, and corresponding spacing and horizontal projection are illustrated in Figure 3-26. The spacing and horizontal projection must be documented in the construction documents.

Figure 3-26 Projection Factor for Horizontal Slats



$$Projection\ Factor = \frac{P}{S} = \frac{D \times \sin(\theta)}{G - D \times \cos(\theta)}$$

P = Projection, S = Spacing, Θ = Angle, G = Gap, D = Depth

D. Distance Factor

If objects exterior to the building are tall enough, they will shade the building's fenestration. In some cases, they may shade enough such that adding horizontal slats to the project adds no benefit. For this reason, horizontal slat installations must also have a minimum distance factor to ensure that any nearby tall objects are far away enough to not cast a substantial shadow on the fenestration. An object casting a shadow can be all or part of an existing structure or natural object such as a chimney on an otherwise flat roof, a decorative feature of a roofline, or even any particular point along a flat roofline, a place on a hilly landscape, a tree on that landscape, or a particular brand on that tree. All of these objects must be evaluated to see if they meet the minimum distance factor requirement.

Distance factor is calculated using the projection factor, the elevation of the windowsill, and the distance and elevation of the top of obstructions within view of the window. To determine the lowest distance factor for the window, all obstructions within view of the window must be considered. This includes building self-shading from walls within view of the window. Distance factor is calculated using Equation 140.3-C. For the PAF, the distance factor must be at least 0.3. Example 3-17 shows how to calculate distance factor.

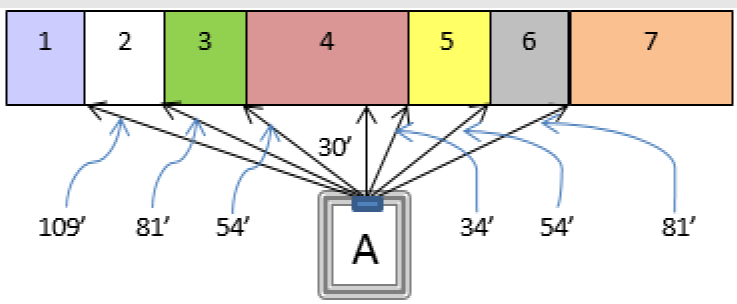
Note that for calculating distance factor, the shape of the obstruction is not accounted for. This is accurate for a situation where the relative heights of obstructions are similar, such as a street with an ordinance on height limit, but it actually may not be relevant if the obstruction does not cast much of a shadow (e.g., a radio tower on a hill).

In these cases, the project may instead demonstrate to the enforcement agency that the fenestration is shaded for less than a certain number of daytime hours between 8 a.m. and 5 p.m. For the PAF, the minimum number of shaded hours is 500. Section 3.3.4.2G shows how to demonstrate shaded hours.

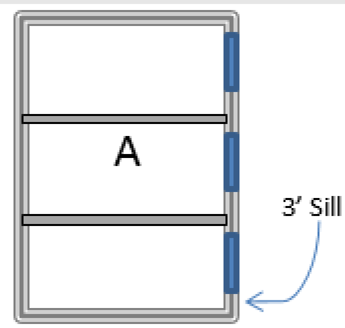
Example 3-17

Question

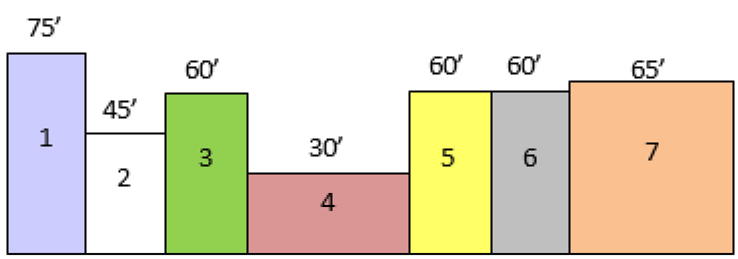
Building A in the diagram below faces east and has a window on the first floor with a sill height of three feet. There are seven buildings within view of this window with the distances and elevations as given in the figures. Can the designer use horizontal slats with a projection factor of 3.0 on this window to receive a PAF?



Site Plan



Building Section



View through Window

Building	Distance [ft]	Elevation [ft]	Distance Factor
1	109	75	0.50
2	81	45	0.64
3	54	60	0.32
4	30	30	0.37
5	34	60	0.20
6	54	60	0.32
7	81	65	0.44

Answer:

No. Building 5 is too close compared to its height.

Equation 140.3-C for distance factor is applied to each of the seven buildings within view of building A. For these buildings, the elevations are the same all along their flat rooftops. So, the objects which might not comply with the minimum distance factor requirement correspond to each of the buildings' rooflines. If we examine the closest point for the rooflines, we will be assured that they will not shade as much or more than the horizontal slats are intended to. The closest point for these rooflines are the sides of the buildings to the side of building A's view (namely, buildings 1-3 and 5-7) and the distance directly across for buildings in front of building A (i.e., building 4). In the case of building 5, this distance factor is

$$Distance\ Factor = \frac{D}{H_{AS} * Projection\ Factor} = \frac{34}{(60-3)*3.0} = 0.2 < 0.3\ (Minimum\ Distance\ Factor)$$

This is lower than the minimum distance factor, so horizontal slats with a projection factor of 3.0 can't be used for the PAF credit.

What can the designer do? The designer may select a lower projection factor or may choose to only use horizontal slats on the 2nd and higher floors of the building which have higher sill elevations.

E. Reflectance and Transmittance

The visible reflectance of horizontal slats must be tested as specified in ASTM E903. Certain coatings for horizontal slats have already been tested per ASTM E903 and can be researched to avoid re-testing. For the PAF, the visible reflectance must be at least 0.50.

If slats are opaque, then they do not require visible transmittance testing. But if they are not opaque, they must be tested as specified in ASTM E1175 and have a visible transmittance of 0.03 or less.

F. Mounting and Adjustability

Horizontal slats must be permanently mounted and not adjustable by occupants or facilities personnel. Horizontal slats are intended to be fixed and unmoving. Venetian blinds do not qualify for the PAF or a performance compliance option. Fasteners such as bolts, welds, and rivets are examples of fasteners that may be used to meet this requirement if they impede the movement of the horizontal slats and the horizontal slat assembly as a whole.

G. Labeling

A factory installed label must be permanently affixed and prominently located on an attachment point of the device to the building envelope. This label spells out that removal of the horizontal slats will trigger re-submittal of compliance documentation to the enforcement agency. If the horizontal slat assembly is removed, the building owners will again need to prove that the building still meets the requirements of the Energy Code with the slats removed.

Specifically, the label must state:

"NOTICE: Removal of this device will require re-submittal of compliance documentation to the enforcement agency responsible for compliance with California Title 24, Part 6."

3.3.11.3 Interior and Exterior Light Shelves

§140.3(d)3

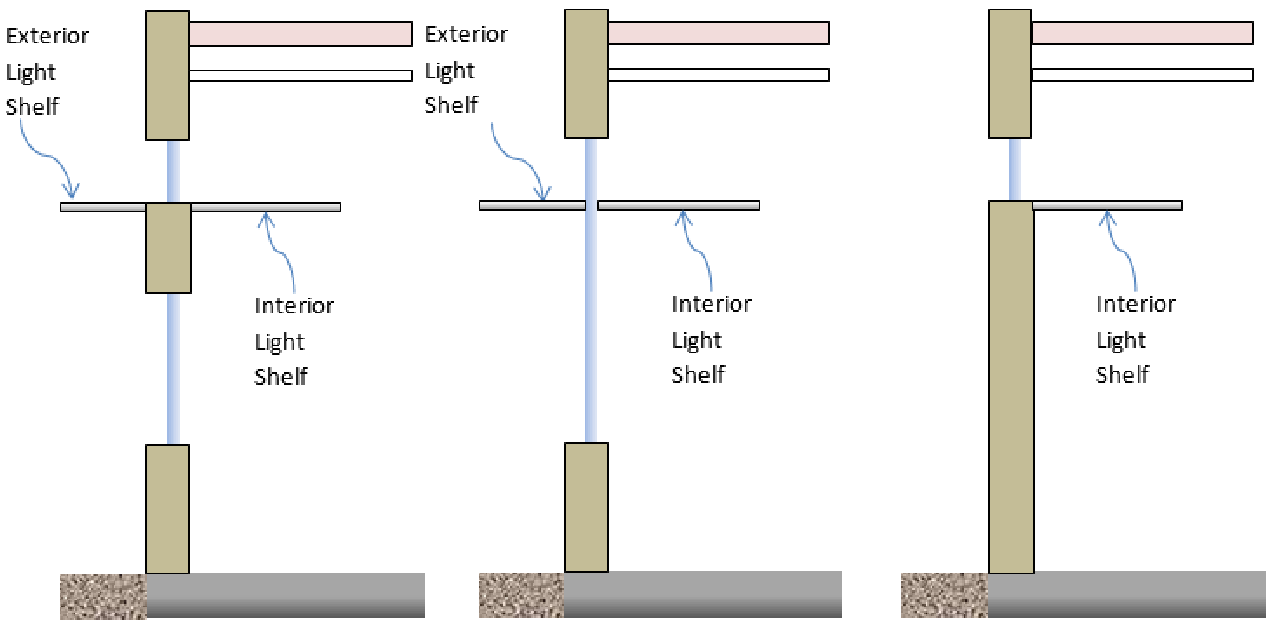
Interior light shelves combined with exterior light shelves on clerestory windows can be used in conjunction with automatic daylighting controls to receive a PAF. Light shelves block and redirect direct sun beam onto the ceiling of a space then reflect it downward into the space.

One pitfall of interior light shelves is the tendency for occupants to place objects on top of them, effectively using them as shelving. Thoughts should be put into the design of interior light shelves to discourage their use in this manner.

A. Exterior Light Shelf Exception and RHSGC

An exterior light shelf also acts as an overhang, blocking direct sun beam through any window area below the clerestory window (view window area). Thus, it may take the overhang SHGC credit. If there is no view window area below the light shelf, then an exterior light shelf may still be installed but it is not required. Diagrams of qualifying interior and exterior light shelf configurations are given in Figure 3-27.

Figure 3-27 Qualifying Interior and Exterior Light Shelves Combinations



B. Clerestory

Light shelves must be installed adjacent to a clerestory window that meets the requirements discussed in the Clerestory Fenestration section, Section 3.3.5.1. In addition, interior light shelves depend on a ceiling to reflect daylight. So, the clerestory window's head must be no greater than one foot below a finished ceiling.

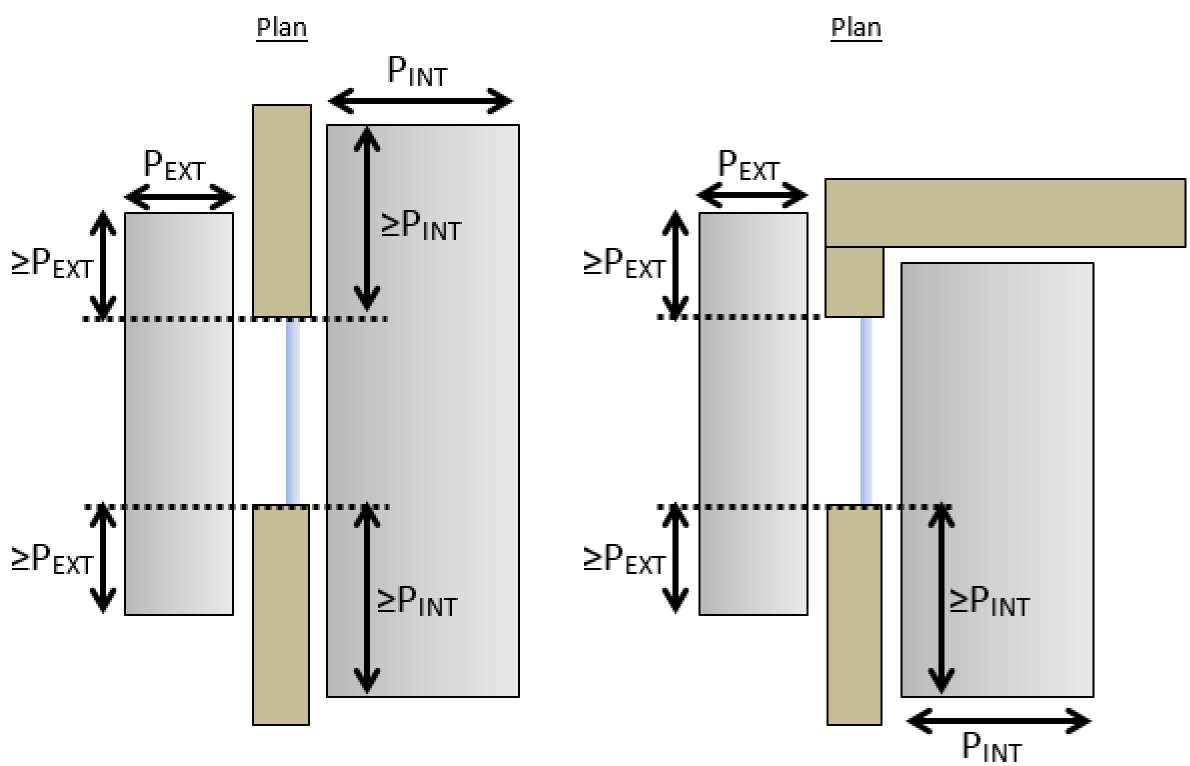
C. Window-to-Wall Ratio (WWR) and Orientation

For the PAF, the WWR must be greater than 30 percent. The light shelves must be mounted on windows on south-facing facades.

D. Side-Shading

Light shelves must block direct beam sunlight at their side edges. At sharp horizontal angles to the window (i.e. high and low relative azimuths), direct beam sunlight still passes through horizontal slats if they are only as wide as the window. Similar to overhangs, light shelves must extend on either side of the window at least as far as their horizontal projection. An example of a qualifying side-shading configuration is given in Figure 3-28.

Figure 3-28 Qualifying Light Shelf Side-Shading Example



E. Projection Factor

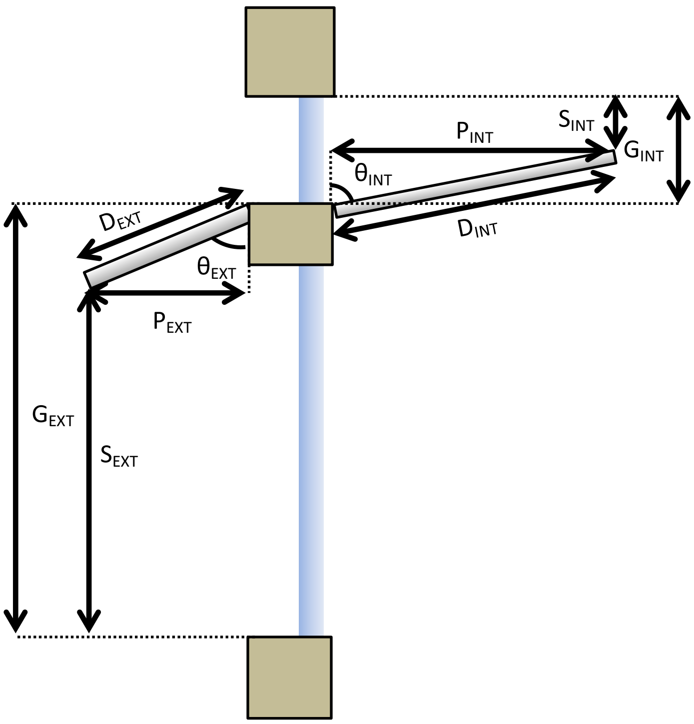
Light shelves must shade direct beam sunlight from above. They may be level or slope downwards when looking out the window (i.e., exterior light shelves slope downwards from fenestration while interior light shelves slope upwards from fenestration). The slopes of interior light shelves should not be too steep or they may block the daylight reflected off of the ceiling, thus reducing the daylighting benefits.

Projection factor is the ratio of the effective horizontal depth to effective vertical spacing of a shading surface. The projection factor is calculated per Equation 140.3-C. For a PAF, the interior light shelf projection factor must be at least 1.0

and not greater than 2.0. The exterior light shelf projection factor must be at least 0.25 and not greater than 1.25.

Light shelf angle, depth, gap, and corresponding spacing and horizontal projection are illustrated in Figure 3-29. The light shelf spacing and horizontal projections must be documented in the construction documents.

Figure 3-29 Projection Factor for Light Shelves



$$Projection\ Factor = \frac{P}{S} = \frac{D \times \sin(\theta)}{G - D \times \cos(\theta)}$$

P = Projection, S = Spacing, Θ = Angle, G = Gap, D = Depth

F. Distance Factor

The requirements and procedures for distance factor are the same as those for horizontal slats as given in the Horizontal Slats section. For the light shelf PAF, the minimum shaded hours are 750 per year.

G. Reflectance

The visible reflectance of the top surface of light shelves must be tested as specified in ASTM E903. If the exterior light shelf is greater than two feet below the clerestory sill, then the top surface of the exterior light shelf needs not be reflective. Certain coatings for light shelves have already been tested per ASTM E903 and can be researched to avoid re-testing.

For the PAF, the visible reflectance must be at least 0.50.

3.4 Relocatable Public School Buildings

§140.3, Table 140.3-D, *Reference Nonresidential Appendix NA4*

Public school building design is defined by these prescriptive requirements:

- Table 140.3-B covers prescriptive requirements for climate-specific relocatable public school buildings.
- Table 140.3-D covers prescriptive requirements for relocatable public school buildings that can be installed in any climate zone.
- Building envelopes must meet the prescriptive requirements in §140.3. For additional design requirements, refer to §140.3 and Reference Appendices, Nonresidential Appendix NA4.

Manufacturers must certify compliance and provide documentation according to the chosen method of compliance. Performance compliance calculations must be performed for multiple orientations, with each model using the same proposed design energy features rotated through eight different orientations either in climate zones 14, 15 or 16, or the specific climate zones in which the relocatable building is installed. Also see §140.3(a)8 and §141.0(b)2.

When the relocatable building is manufactured for use in specific climate zones and cannot be lawfully used in other climate zones, the energy budget must be met for each climate zone that the manufacturer/building certifies, using prescriptive envelope criteria in Table 140.3-B. The energy budget and the energy use of the proposed building must be determined using the multiple orientation approach specified in the Reference Appendices, Nonresidential Appendix NA4. The manufacturer/builder shall meet the requirements for identification labels specified in §140.3(a)8.

When the manufacturer/builder certifies a relocatable public school building for use in any climate zone, the building must be designed and built to meet the energy budget for the most severe climate zones (as specified in the Reference Appendices, Nonresidential Appendix NA4), assuming the prescriptive envelope criteria in Table 140.3-D of the Energy Code.

3.5 Performance Approach

§140.1

Under the performance approach, energy use of the building is modeled by compliance software approved by the Energy Commission. The compliance software simulates the time-dependent value (TDV) energy use of the proposed building, including a detailed accounting of envelope heat transfers using the assemblies and fenestration input, and the precise geometry of any exterior overhangs or side fins. The most accurate tradeoffs between different envelope components – and among the envelope, the space-conditioning system, and the installed lighting design – are accounted for and compared with the standard design version of the building. The proposed design must have TDV energy less than or equal to the standard design.

This section presents some basic details on the modeling of building envelope components. A discussion on the performance approach, and fixed and restricted inputs, is included in Chapter 11. The following modeling capabilities are required by all approved nonresidential compliance software. These modeling features affect the thermal loads seen by the HVAC system model. More information may be found in the *ACM Reference Manual* and the CBECC User Guide.

3.5.1 Compliance Modeling

3.5.1.1 Mass Characteristics

Heat absorption, retention, and thermal transfer characteristics associated with the heat capacity of exterior opaque mass surfaces such as walls, roofs and floors are modeled.

Typical inputs are:

- Spacing
- Thickness
- Standard U-factor
- Reference Appendices, Joint Appendix JA4 table
- Framed cavity R-value
- Proposed assembly U-factor.

The heat capacity of concrete masonry unit walls and solid concrete walls is provided in Tables 4.3.5 and 4.3.6 of Reference Appendices, Joint Appendix JA4. Effective R-values for interior and exterior insulation are provided in Table 4.3.13 of Reference Appendices, Joint Appendix JA4.

3.5.1.2 Opaque Surfaces

Heat gains and heat losses are modeled through opaque surfaces of the building envelope. The following inputs or acceptable alternative inputs are used by this modeling capability:

- Surface areas by opaque surface type.
- Surface orientation and slope.
- Thermal conductance of the surface. The construction assembly U-factor is developed by specifying a construction as a series of layers of building materials, each of which represents insulation, framing, homogenous construction material, or a combination of framing and cavity insulation.

- Surface absorptance = 1– solar reflectance. Surface absorptance is a restricted input (except for roofs).

Note for roofs: Surface absorptance and emittance are variable inputs in the proposed design for roofs to provide design flexibility where a cool roof is not specified. The roof reference design is set with a cool roof surface absorptance for nonresidential buildings in all climate zones. The difference in surface absorptance creates a credit that can be used with the whole-building performance method. For more information on cool roofs, see Section 3.2.4.

To model the proposed design as a cool roof, the roofing product must be listed in the directory of the CRRC. If the roof is not rated, a default aged reflectance of 0.08 is used for asphalt or composition shingles and 0.10 for other roofing products. If the proposed design does not have a cool roof, the performance method may be used to trade off with other features, such as increased insulation or HVAC equipment efficiency, so that the TDV energy of the proposed design does not exceed that of the standard design.

3.5.1.3 Fenestration

Heat transfer through all fenestration surfaces of the building envelope are modeled using the following inputs:

- Fenestration areas. The glazing width and height dimensions are those of the rough opening for the window or fenestration product. Window area of the standard design is limited to the prescriptive limit of 40 percent of the gross exterior wall area (that is adjacent to conditioned space) or six times the display perimeter, whichever is greater. If the proposed design window area exceeds this limit, a trade-off may be made with features such as increased envelope insulation or increased equipment efficiency to offset the penalty from fenestration.
- Fenestration orientation and slope. Vertical windows installed in a building located in any of the four cardinal orientations, north, south, west, and east. Skylights are considered less than 60º from the horizontal, and all windows and skylights provide solar gain that can affect the overall energy of the building unless they are insulated glass.
- Fenestration thermal conductance (U-factor). The overall U-factor shall be taken from NFRC rating information, default values in Table 110.6-A of the Energy Code, or from Reference Appendices, Nonresidential Appendix NA6 if less than 200 ft² of site-built skylight area, and alterations to vertical fenestration.
- Fenestration solar heat gain coefficient (SHGC). The SHGC shall be taken from NFRC rating information default values in Table 110.6-B of the Energy Code or from Reference Appendices, Nonresidential Appendix NA6 if less than 200 ft² of site-built skylight area, and alterations to vertical fenestration. The baseline

building uses a SHGC equal to the value from Tables 140.3-B, 140.3-C, or 140.3-D. The baseline building has no overhangs, but overhangs can be modeled in the baseline building.

- Visual Transmittance

3.5.1.4 Overhangs and Vertical Shading Fins

Approved compliance software programs are able to model overhangs and vertical fins. Typical inputs for overhangs are:

- Overhang projection.
- Height above window.
- Window height.
- Overhang horizontal extension past the edge of the window.
  - If the overhang horizontal extension (past the window jambs) is not an input, then the program assumes that the extension is zero (that is, overhang width is equal to window width), which results in fewer benefits from the overhang.

Vertical fins are modeled with inputs of horizontal and vertical position relative to the window, the vertical height of the fin and the fin depth (projection outward perpendicular to the wall).

3.5.1.5 Slab-on-Grade Floors and Basement Floors

Heat transfer through slab-on-grade floors and basement floors is modeled by calculating perimeter heat losses and interior slab heat losses. The heat losses from the perimeter and the interior are modeled by the use of an F-factor that accounts for the rate of heat transfer from the slab to the soil. Reference Appendices, Joint Appendix JA4 contains F-factors for common insulation conditions (vertical insulation outside or a combination of the two: horizontal and vertical). The insulation depth and insulation R-value affect heat loss through basement floors.

3.6 Additions and Alterations

§141.0

The Energy Code offers prescriptive approaches and a performance approach to additions and alterations, but they do not apply to repairs. See §141.0(a) and §100.1(b) for detailed definitions.

A. Addition is a change to an existing building that increases conditioned floor area and volume. When an unconditioned building or unconditioned part of a building adds heating or cooling so that it becomes newly conditioned for the first time, this area is treated as an addition.

B. Alteration is a change to an existing building that is not an addition. An alteration could include a new HVAC system, lighting system, or change to the building envelope, such as a new window. Roof replacements (reroofing) and reconstructions and renewal of the roof are considered alterations and are subject to all applicable Energy Code requirements. For alterations, the compliance procedure includes:

1. The prescriptive envelope component approach.
2. The existing-plus-alteration performance approach.
3. The existing-plus-addition-plus alteration performance approach.

C. Repair is the reconstruction or renewal of any part of an existing building for maintenance. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is an alteration.

For example, a repair could include the replacement of a pane of glass in an existing multi-lite window without replacing the entire window.

Additions and alterations to the building envelope must meet the prescriptive insulation requirements in §141.0 or comply using the performance compliance approach.

3.6.1 Mandatory Requirements

3.6.1.1 Additions

All additions must meet the applicable mandatory requirements from the following Energy Code sections:

- §110.6 – Mandatory Requirements for Fenestration Products and Exterior Doors
- §110.7 – Mandatory Requirements for Joints and Other Openings
- §110.8 – Mandatory Requirements for Insulation and Roofing Products (Cool Roofs)
- §120.7– Mandatory Requirements for Insulation.

3.6.1.2 Alterations

§141.0(b)1

All alterations must meet the mandatory requirements of §110.6, §110.7, and §110.8.

A. Wall Insulation

Insulation for walls that separate conditioned space from either unconditioned space or ambient air shall comply with the mandatory requirements of §141.0(b)1B. This section provides two options for wall insulation compliance: either a minimum insulation R-value or a maximum assembly U-factor. The mandatory requirements are determined by the wall type per Table 3-17:

Table 3-17 Wall Insulation for Alterations

Wall Assembly Type	Minimum R-value	Maximum U-factor
Metal buildings	R-13	0.113
Metal-framed walls	R-13	0.217
Wood-framed walls and others	R-11	0.110
Spandrel panel and curtain walls	R-4	0.280

Light mass and heavy mass walls do not have mandatory requirements for minimum R-value and maximum U-factor.

B. Floor Insulation

Insulation for floors that separate conditioned space from either unconditioned space or ambient air shall comply with the mandatory requirements of §141.0(b)1C. This section provides two options for compliance with the mandatory requirements: either a minimum insulation R-value or a maximum assembly U-factor. For floors, the mandatory requirements are determined by both building type and floor type.

Table 3-18 Floor Insulation for Alterations

Floor Assembly Type	Minimum R-value	Maximum U-factor
Raised framed floors	R-11	0.071
Raised mass floors in high rise, hotel and motel	R-6	0.111

Raised mass floors in all other occupancies - No minimum U-factor is required.

3.6.2 Prescriptive Requirements

For more details on the prescriptive requirements, see Section 3.2 for envelope requirements and Section 3.3 for fenestration requirements.

3.6.2.1 Additions

§141.0(a)1

Prescriptive compliance for the building envelope of additions is addressed in §141.0(a)1 and §140.3. §140.3(a) provides prescriptive compliance alternatives for the building envelope, including tradeoffs between roofing insulation and the solar reflectance of roofing products (cool roofs) in Table 140.3-A. Tradeoffs between other envelope components are not allowed in the prescriptive method. The performance method may be used for tradeoff for both newly constructed buildings and alterations.

All additions must also comply with §140.3(c), Minimum Skylight Area, for large, enclosed spaces in buildings with three or fewer stories.

Alternatively, the addition may meet compliance by using the performance compliance approach of §140.1, which compares the TDV energy (space conditioning, lighting, and water heating) of the proposed building addition to a TDV energy budget that complies with prescriptive requirements.

3.6.2.2 Alterations

§141.0(b)2

In general, any alteration to an existing building that involves changes to a portion of the building envelope triggers the Energy Code. The prescriptive requirements for alterations to building envelopes are in §141.0(b)2A and B of the Energy Code.

The altered components of the envelope shall meet the applicable mandatory requirements of §110.6, §110.7 and §110.8.

A. Fenestration

When fenestration is altered that does not increase the fenestration area, it shall meet the requirements of Table 141.0-A of the Energy Code (Table 3-19) based on climate zone.

When new fenestration area is added to an alteration, it shall meet the requirements of §140.3(a) and Tables 140.3-B, C or D of the Energy Code. Compliance with §140.3(a) is not required when the fenestration is temporarily removed and then reinstalled.

In cases where small amounts of fenestration area are changed, several options exist.

- If less than 150 ft² of fenestration area is replaced throughout the entire building, then the Energy Code require that only the U-factor requirements in Tables 140.3-B, C, or D are met. The SHGC, RSHGC, or VT requirements need not be met.
- The same requirements and exceptions apply if 50 ft² or less of fenestration (or skylight) area is added. A typical example of this may be changing a door from a solid door to a glass door.

Table 3-19: Altered Window Maximum U-Factor and Minimum RSHGC and VT

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

U-factor	0.47	0.47	0.58	0.47	0.58	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
SHGC	0.41	0.31	0.41	0.31	0.41	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.41

Note : For VT See Table 140.3-B, C, and D for all Climate Zones

Energy Code, Table 141.0-A

Example 3-18

Question:

The envelope and space conditioning system of an office building with 120,000 square feet of conditioned floor area is being altered. The building has 24,000 square feet of vertical fenestration. Which of the following scenarios does the NFRC label certificate requirement apply to?

1. Existing glazing remains in place during the alteration.
2. Existing glazing is removed, stored during the alteration period, and then reinstalled (glazing is not altered in any way).
3. Existing glazing is removed and replaced with new site-built glazing with the same dimensions and performance specifications.
4. Existing glazing on the north façade (total area 800 square feet) is removed and replaced with site-built fenestration.

Answer:

NFRC label certificate or California Energy Commission default values requirements do not apply to Scenarios 1 and 2 but do apply to Scenario 3.

1. Requirement does not apply because the glazing remains unchanged and in place.
2. *Exception* to §110.6(a)1 applies to fenestration products removed and reinstalled as part of a building alteration or addition.
3. Use either NFRC label certificate or use Tables 110.6-A and 110.6-B default values; applies in this case as 24,000 ft² of new fenestration is being installed.
4. Since the site-built vertical fenestration area is being used as part of an alteration use either the NFRC label certificate, the applicable default U-factor or SHGC set forth in Reference Nonresidential Appendix NA6, or default values from Tables 110.6-A and 110.6-B.

B. Walls and Floors

All nonresidential building alterations involving exterior walls, demising walls, external floors, or soffits must either comply as a component with the requirements in Tables 140.3-B, C, or D in the Energy Code, or by approved compliance software following the rules of the *ACM Reference Manual* that demonstrates that the overall TDV energy use of the altered building complies with the Energy Code.

C. Air Barrier

If 25 percent or more of the building envelope's wall area is altered it needs to meet the air barrier design and material requirements for newly constructed buildings. See Section 3.2.3.2 for detailed guidance on the air barrier requirements for newly constructed buildings and how to perform the blower door testing.

If a blower door test is performed and the air leakage rate exceeds 0.4 cfm/ft2 a Visual Inspection and Diagnostic Evaluation must be completed in accordance with Nonresidential Appendix NA5.7 to find the sources of excessive leakage. The leaks shall then be sealed. An additional report identifying the corrective actions taken to seal air leaks should be submitted to the building owner and code official. Retesting is not needed.

Additions that do not have a completely separate air barrier from the existing building – there is not wall separating the two – shall be temporarily partitioned in order to conduct the air leakage test if the pressurization test is chosen to comply with the requirements of 140.3(a)9C.

D. Roofs

Existing roofs being replaced, recovered, or recoated for nonresidential, high-rise residential and hotels/motels buildings shall meet the requirements of §110.8(i). When the alteration is being made to 50 percent or more of the existing roof area or when more than 2,000 ft^2 of the roof is being altered, (whichever is less) the requirements apply. When a small repair is made, these requirements do not apply. For example, the requirements for roof insulation would not be triggered if the existing roof surface were overlaid instead of replaced.

These requirements apply to roofs over conditioned, non-process spaces even if the building has a portion that is a process space. These roof areas can be delineated by the fire separation walls between process areas and conditioned, non-process areas.

The California Building Code (CBC) and local amendments place limitations on the number of new roof covering layers that are allowed to overlay an existing roof covering in accordance with CBC 1510. When this limit is reached, the existing roof covering must be removed down to the roof deck or insulation recover boards.

E. Roof Insulation

When a roof is replaced or recovered, and the alteration complies with the prescriptive requirements for roofing products, the altered roof area shall be insulated to the levels specified in Table 141.0-C of the Energy Code (Table 3-20).

Roof replacement and roof recover are defined in Title 24, Part 2, Chapter 2 – Definitions. A roof replacement is the process of removing the existing roof covering, repairing any damaged substrate and install a new roof covering. A roof recover is the process of installing an additional roof covering over a prepared existing roof covering without removing the existing roof covering. Roof recovers are typically a less expensive option but can only be performed if the existing roof is in good condition. Usually, one roof recover is allowed before the roof needs to be replaced. Title 24, Part 2, Chapter 15 does not permit roof recovers where the existing roof or roof covering is water soaked or has deteriorated to the point where it is not an adequate base for additional roofing; where the existing roof covering is slate, clay, cement, or asbestos-cement title; or where the existing roof has two or more applications of any type of roof covering.

The amount of insulation required varies by climate zone and building type. The requirements are given in terms of a continuous layer of insulation (usually installed on top of the roof deck) or an overall roof U-factor based on the default tables and calculation method in Reference Appendices, Joint Appendix JA4. The U-factor method provides more flexibility, as insulation can be added continuously on top of the roof deck, below the roof deck between roof joists, or a combination of insulation above and below the roof deck.

Table 3-20: Nonresidential Insulation Requirements for Roof Alterations

Climate Zone	Continuous Insulation R-value	U-Factor
1-5 and 9-16	R-23	0.037, with at least R-10 above deck
6-8	R-17	0.047, with at least R-10 above deck

Source: Energy Code, Table 141.0-C

For roof alterations, when roofs are replaced or recovered and meet the roofing products requirements in §141.0(b)2Bi or ii, the altered area must be insulated to levels specified in the Energy Code, Table 141.0-C. For nonresidential buildings, this level is:

- R-17 or R-23 (depending on climate zone) with the use of continuous insulation; or
- U-0.047 or U-0.037 (depending on climate zone) if the insulation is a combination of above deck continuous insulation and cavity insulation. Under the U-factor option, at least R-10 of continuous insulation must be installed above the roof deck.

Exceptions to §141.0(b)2Bii:

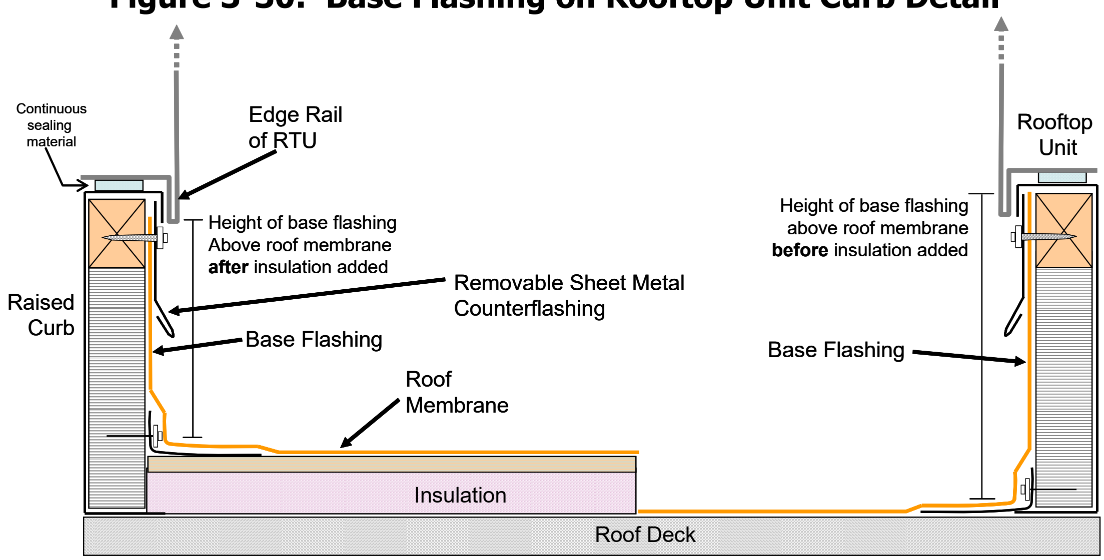
- Roof recovers with new R-10 insulation added above deck do not need to be insulated to the level specified in Table 141.0-C.
- When mechanical equipment located on the roof will not be disconnected and lifted as part of the roof replacement, insulation added may be the greater of R-10 or the maximum installed thickness that will allow the distance between the height of the roof membrane surface to the top of the base flashing to remain in accordance with the manufacturer’s instructions.

- Increasing the elevation of the roof membrane by adding insulation may also affect roof drainage. The Energy Code allows tapered insulation to be used that has a thermal resistance less than that prescribed in Table 141.0-C at the drains and other low points, provided that the thickness of insulation is increased at the high points of the roof so that the average thermal resistance equals or exceeds the value that is specified in Table 141.0-C.

When insulation is added on top of a roof, the elevation of the roof membrane is increased. When insulation is added to a roof and the curb height (counterflashing for walls) is unchanged (Figure 3-30), the height of the base flashing above the roof membrane will be reduced. In some cases, when the overhanging edge of the space-conditioning equipment is very close to the side of the curb, this may also limit how far up the curb the base flashing may be inserted. Many manufacturers and the National Roofing Contractors Association (NRCA) recommend maintaining a minimum base flashing height of 8 inches above the roofing membrane.

When adding insulation on top of a formerly uninsulated or under-insulated roof, consider the effects on base flashing height. It may be desirable to increase curb heights or counterflashing heights to maintain the same or higher base flashing heights above the roof membrane. In other cases, where leak risk is low, ask the roofing manufacturer for a variance on installation requirements for a roofing warranty; this may require additional waterproofing measures to obtain the manufacturer's warranty. Installing insulation under the roof deck when access is feasible doesn't change the base flashing height and, in some cases, may be the least expensive way to insulate the roof.

Figure 3-30: Base Flashing on Rooftop Unit Curb Detail



F. Roof Products

§141.0(b)2B

1. Thermal Emittance and Aged Solar Reflectance Prescriptive Requirements

For nonresidential buildings, the prescriptive requirements for roofing products are:

- Low-sloped roofs in climate zones 1 through 16 have a required minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75, or a minimum SRI of 75.
- Steep-sloped roofs in climate zones 1 and 3 have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16. climate zones 2 and 4 through 16 have a minimum aged solar reflectance of 0.25 and a minimum emittance of 0.80, or a minimum SRI of 23.

Exception for nonresidential buildings: an aged solar reflectance less than 0.63 is allowed, provided that additional insulation is installed. (Table 3-21)

For hotel and motel buildings, the prescriptive requirements for roofing products are:

- Low-sloped roofs in climate zones 10, 11, 13, 14 and 15 have a required minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.
- Steep-sloped roofs in climate zones 2 through 15 have a required minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

Exceptions for hotel and motel buildings:

- For roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels, roofing products are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.
- For roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft² roofing products are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

U-factors measure the thermal performance of the entire roof assembly, both above and below the roof deck. Utilizing U-factors provides flexibility. Trade-offs can be made by installing additional insulation continuously above the roof deck, between the joists below the roof deck, or a combination of both approaches. Table 141.0-B (Table 3-21) shows the overall roof U-factors trade-off requirements, by climate zones.

Table 3-21: Roof/Ceiling Insulation Trade-Off for Aged Solar Reflectance

Aged Solar Reflectance	Climate Zone 1, 3-9 U-factor	Climate Zone 2, 10-16 U-factor
0.62 - 0.60	0.043	0.035
0.59 - 0.55	0.041	0.034
0.54 - 0.50	0.038	0.031
0.49 - 0.45	0.034	0.029
0.44 - 0.40	0.032	0.028
0.39 - 0.35	0.029	0.026
0.34 - 0.30	0.028	0.025
0.29 - 0.25	0.026	0.024

Energy Code, Table 141.0-B

Table 141.0-B of the Energy Code not only takes account of the amount of insulation necessary to compensate for using a noncompliant roofing product, it also accounts for the minimum insulation requirements that apply to roof alterations generally.

Example 3-19

Question:

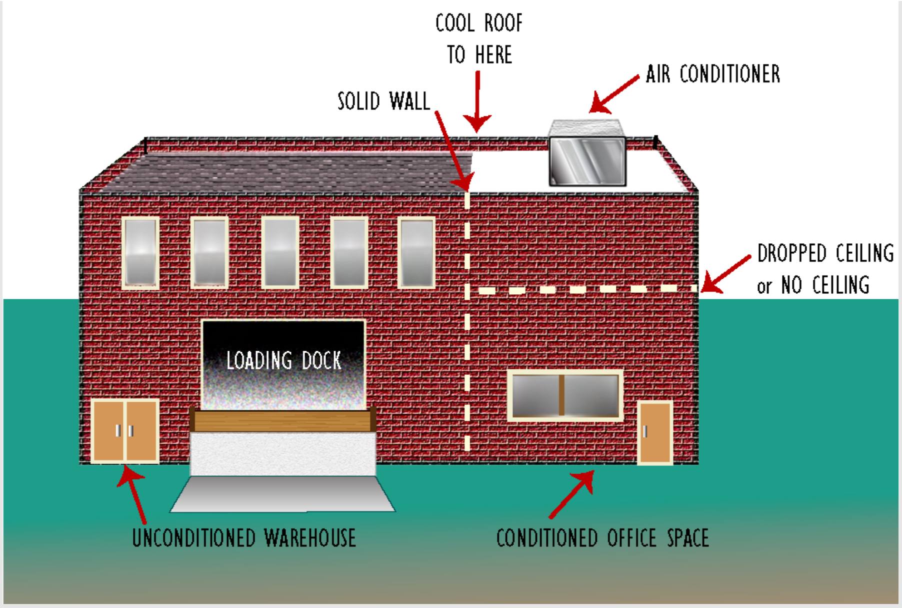
What are the Energy Code requirements for cool roofs when reroofing a low-sloped roof on an unconditioned warehouse containing conditioned office space?

Answer:

Scenario 1.

There is either directly or indirectly conditioned space under the roof. The cool roof requirements apply to just the portion(s) of the warehouse roof over the conditioned space(s). The rest of the roof (over unconditioned warehouse space) is not required to be a cool roof.

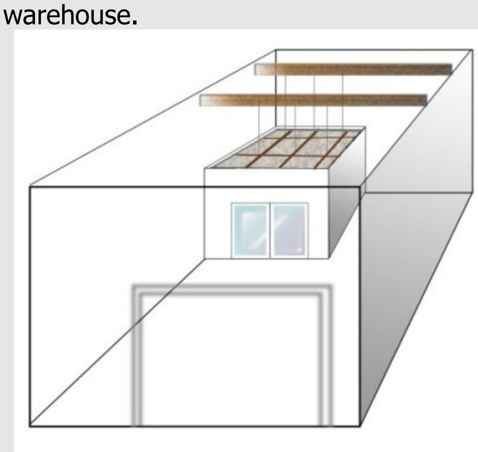
The walls of the conditioned space go all the way up to the underside of the warehouse.



Source: California Statewide CASE Team

Scenario 2.

The walls of the conditioned space do not reach all the way to the warehouse roof. The roof requirements do not apply because the space directly below the roof is unconditioned and communicates with the rest of the unconditioned portion of the warehouse.



Example 3-20

Question:

I have a barrel roof on nonresidential conditioned building that needs to be reroofed. Must I follow the Energy Code roofing product requirement?

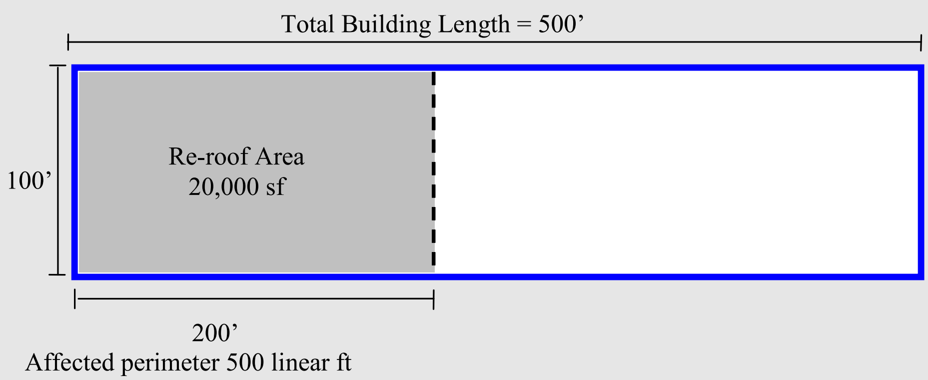
Answer:

Yes, the roof would need to meet the aged solar reflectance and thermal emittance for a steep-sloped roof. Although a barrel roof has both low-sloped and steep-sloped roofing areas, the continuous gradual slope change allows the steep-sloped section of the roof to be seen from ground level. Barrel roofs only need to meet the steep-sloped requirement for the entire roof area.

Example 3-21

Question 1:

40 percent of the low-sloped roof on a 500 ft by 100 ft retail building in Concord, California (CZ12,) is being reroofed. The roofing is removed down to the roof deck, and there is no insulation. Must insulation be added before reroofing?



Answer 1:

Yes, §141.0(b)2B requires when either 50 percent (or more) of the roof area or 2,000 ft² (whichever is less) is reroofed down to the roof deck or recover boards, that insulation be installed if the roof has less than the insulation in Energy Code Table 141.0-C. Though the reroofing covers only 40 percent of the roof area, the requirements still apply because the 20,000 ft² of replacement roof area is greater than the threshold area of 2,000 ft². The roof does not have any insulation and, therefore, is required to add insulation. As per Energy Code, Table 141.0-C Insulation Requirements for Roof Alterations, for nonresidential buildings in climate zone 12, the requirement for insulation is either R-23 continuous insulation (e.g., 4-inches of polyisocyanurate (polyiso) rated at R-5.7/inch) or an effective roof U-factor of 0.037 Btu/h•ft²•°F with at least R-10 continuous insulation installed above deck.

Question 2:

If the building is in San Francisco, would the insulation requirements be different on the building?

Answer 2:

No. San Francisco (as shown in Reference Appendices, Joint Appendix JA2) is in climate zone 3. Per Table 141.0-C from §141.0(b)2B, the insulation requirement for roof alterations for nonresidential buildings in climate zone 3 is R-23 or a U-factor of 0.037 with at least R-10 continuous insulation installed above deck.

Example 3-22

Question 1:

A nonresidential building is having 5,000 ft² of roofing replaced in Richmond (climate zone 3). During roofing replacement the roof deck will be exposed. This building has a rooftop air conditioner that is sitting on an 8-inch-high curb above the roof membrane level. The roof is uninsulated. If the rooftop air-conditioner unit is not disconnected and not lifted off the curb during reroofing, is adding insulation required? If so, how much?

Answer 1:

Yes, the only time insulation is not required to be added is if the roof already meets the insulation requirements in Energy Code Table 141.0-C. However, the exception to §141.0(b)2Bii allows for less insulation to be installed if the space conditioning equipment is not disconnected and lifted during reroofing. In this case, the requirements for adding insulation are limited to the greater of R-10 (e.g., 1.75 inches of polyisocyanurate insulation rated at R-5.7/inch) or the maximum installed thickness that will allow the distance between the height of the roof membrane surface to the top of the base flashing to remain in accordance with the manufacturer's instructions. Ask the roofing manufacturer what the lowest curb height is that they will provide a warranty for: if it is 6.25 inches or lower (8-inch curb height – 1.75 inches of polyiso), install the maximum amount of insulation to remain in accordance with the manufacturer's instructions. If it is higher than 6.25 inches and therefore it is not possible to install R-10 or greater, the space conditioning must be disconnected and lifted, the curb must be replaced or a curb extension added, and the full insulation required by Energy Code Table 141.0-C must be added, in this case R-23 or U-0.037 with at least R-10 above deck.

Question 2:

What if the rooftop air conditioner is lifted temporarily during reroofing to remove and replace the roofing membrane? How much i added insulation is required?

Answer 2:

The insulation required by Energy Code Table 141.0-C must be added, in this case R-23 or U-0.037 with at least R-10 above deck.

When the rooftop unit is lifted as part of the reroofing project, the incremental cost of replacing the curb or adding a curb extension is reduced and therefore the exception does not apply.

Thus, to maintain the 8-inch base flashing height, one can replace the curb or add a curb extension before reinstalling the roof top unit. Alternatively, one can ask for a roofing manufacturer's variance to the warranty from the typical minimum required 8 inches base flashing height above the roof membrane to the reduced amount after the roof insulation is installed. The specific risk of roof leakage at a given site has to be considered carefully before reducing the base flashing height. An alternative method of compliance that does not affect base flashing heights is to add insulation below the roof deck to the overall U-factor levels given in Table 141.0-C of §141.0(b)2B.

Example 3-23

Question:

A nonresidential building is having 5,000 ft² of roofing replaced. During roofing replacement, the roof deck will be exposed. This building has several unit skylights that are sitting on an 8–inch-high (20 cm) curb above the roof membrane level. The roof is uninsulated. Is added insulation required?

Answer:

Yes, insulation is required. There are no exceptions for skylights. Removing a unit skylight and increasing its curb height is substantially less effort than that for space-conditioning equipment.

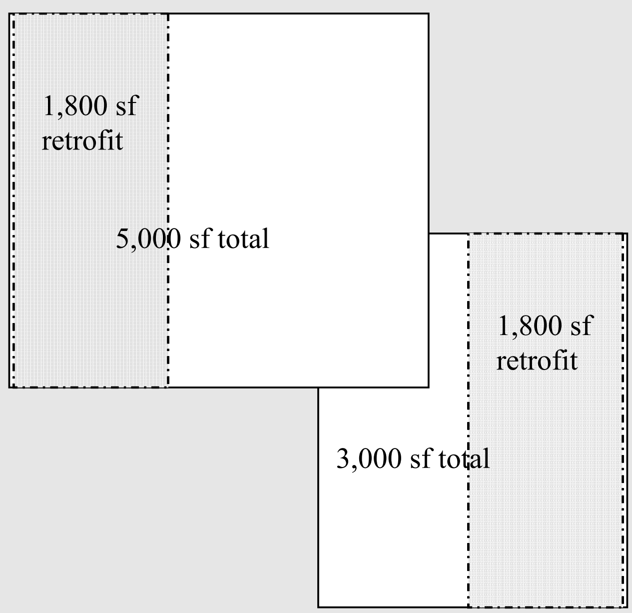
Example 3--24

Question 1:

A building has low-sloped roofs at two elevations. One roof is 18 feet above grade and has a total area of 5,000 ft²; the other roof is 15 feet above grade and has a total area of 3,000 ft². Both roofs are uninsulated and are above conditioned space. If 1,800 ft² of the 3,000 ft² roof is being reroofed and the roof deck is exposed, is that portion of the roof required to be insulated and be a cool roof (high reflectance and emittance)?

Answer 1:

Yes, the reroofed section of the roof must be insulated and have a cool roof. Section 141.0(b)2B requires insulation and cool roofs for low-sloped roof alterations if the alteration is greater than 2,000 ft² or greater than 50 percent of the roof area. Since 1,800 ft² is 60 percent of 3,000 ft², the cool roof and insulation requirements apply.



Question 2:

If the 1,800 ft² of roofing being replaced was on the 5,000 ft² uninsulated roof, would the portion of the roof replaced be required to be a cool roof and have insulation installed?

Answer 2:

No. The 1,800 ft² retrofit is 36 percent of the 5,000 ft² roof. Thus, the 1,800 ft² retrofit is less than 50 percent of the roof area and it is less than 2,000 ft²; thus, it is not required to comply with the insulation and cool roof requirements in §141.0(b)2B.

Example 3--25

A 10,000 ft² building in climate zone 10 with an uninsulated roof above conditioned space is having roofing removed so that the roof deck is exposed. There are two rooftop units on this section of the roof that is being altered. One rooftop unit has a curb with a 9-inch base flashing, and the other has a modern curb with a 14-inch base flashing. Consider the following three scenarios:

Question 1: The rooftop unit with the 9-inch base flashing is disconnected and lifted during reroofing. However, the rooftop unit on the curb with the 14-inch (36 cm) base flashing is not lifted. In this situation, is the insulation added limited to the greater of R-10 or the maximum installed thickness that will allow the distance between the height of the roof membrane surface to the top of the base flashing on the unit with the lower curb to remain in accordance with the manufacturer's instructions?

Answer 1:

No. The unit with the 9-inch base flashing was disconnected and lifted and thus it does not qualify for the exception to §141.0(b)2Bii. There is plenty of room to meet the insulation requirements in Energy Code Table 141.0-C in any climate zone without impacting the unlifted rooftop unit with a 14-inch curb.

Question 2:

The rooftop unit with the 9-inch base flashing is not disconnected and lifted during reroofing. In this situation Does an exception apply for the amount of insulation that must be added?

Answer 2:

Yes. The unit with the 9-inch (23 cm) base flashing was not disconnected and lifted, and thus it qualifies for the exception 2 to §141.0(b)2Bii. This should be handled in the same way as Example 3-22, Question 1, above.

Question 3:

In Question 2, does this reduced amount of required insulation apply only to the area immediately surrounding the unlifted unit or to the entire roof?

Answer 3:

The reduced amount of insulation applies to the entire roof. However, if a building has multiple roofs, the limitation would apply only to any roof with a rooftop unit that was not disconnected and lifted and that has a low curb.

Example 3--26

Question:

In reroofing, is existing roofing that is a rock or gravel surface equivalent to a gravel roof over an existing cap sheet, and therefore qualify for the exceptions in 140.3(a)Ai?

Answer:

No, the two roofs are not equivalent (rock or gravel roofs do not perform the same as gravel roofs over an existing cap sheet), and, therefore, the gravel roof over existing cap sheet may not qualify for the exception.

Example 3--27

Question:

If I am doing a reroof, would Exceptions 1 through 4 to §140.3(a)1Ai apply to reroofing and roof alterations?

Answer:

Yes, these exceptions apply to reroofing and alterations, and the roofs that meet one or more of these exceptions are exempt from the cool roof requirements.

Example 3-28

Question:

What happens if I have a low-sloped roof on most of the building but steep-sloped on another portion of the
roof? Do I have to meet two sets of rules in §141.0(b)2Bi and ii?

Answer:

Yes, the low-sloped portion of the roof must comply with the requirements for low-sloped roofs, while the steep-sloped portion of the roof must comply with the requirements for steep-sloped roofs. These requirements are climate zone-based.

Example 3-29

Question:

A low-sloped nonresidential building in Santa Rosa needs to be reroofed. It has a wood-framed rafter roof. The rafters are 2x4's spaced 16 inches on center. The owner wants to install a roofing product with an aged reflectance of 0.60, which is less than the prescriptive standard of 0.63. Can I install additional insulation to make up for the shortfall in reflectance?

Answer:

Yes.

To make an insulation/reflectance trade-off under the prescriptive approach, using Table 141.0-B. Look up in the table the maximum roof/ceiling insulation U-factor for the aged solar reflectance of the roofing product and the climate zone in which the building is located. In this case, the roofing product has an aged reflectance of 0.60, and Santa Rosa is in climate zone 2, so the appropriate U-factor is found in row 1, column 2 of the table. It is 0.052. Consult Section 4.2 (Roofs and Ceilings) of Reference Appendices, Joint Appendix JA4 to find the U-factor table for the type of roof in question. Reference Appendices, Joint Appendix JA4 can be accessed on the Commission's website at http://www.energy.ca.gov/title24/2022standards/.

The appropriate table in this case is Table 4.2.2, U-factors of Wood Framed Rafter Roofs. Locate the section of the table that pertains to 2x4 rafters spaced 16 inches on center. There are several U-factors in this area of the table that are equal to or less than 0.052. A combination of R-11 cavity insulation and R-8 continuous insulation, for example, has a U-factor of 0.050. Similarly, a combination of R-13 cavity insulation and R-6 continuous insulation has a U-factor of 0.052. Any U-factor that is equal to or less than 0.052 represents a combination of above- and below-deck insulation that complies with the requirements for the proposed trade-off.

Example 3-30

Question:

There are several exceptions to the minimum insulation requirements for roof alterations. Can these be used to limit the insulation required to make a trade-off under Table 141.0-B?

Answer:

No. The exceptions to §141.0(b)2Biii do not apply to trade-off situations. They apply only when a compliant roofing product is being installed and no trade-off is involved.

3.6.3 Performance Requirements

3.6.3.1 Additions

The envelope and indoor lighting in the conditioned space of the addition, and any newly installed space-conditioning system or water-heating system serving the addition, shall meet the applicable requirements of §110.0 through §130.5; and either 1 or 2 below:

1. The addition alone shall comply with §141.0(a).
2. Existing plus addition plus alteration. The standard design building is the reference building against which the altered building is compared. The standard design building uses equivalent building envelope, lighting, and HVAC components when those components are not altered. For components that are altered or added, the standard design uses either the prescriptive requirements for newly constructed buildings or the envelope requirements specified in §141.0. The proposed design energy use is the combination of the unaltered components of the existing building to remain and the altered component's energy features, plus the proposed energy features of the addition.

EXCEPTION to Additions - Performance Approach: Additions that increase the area of the roof by 2,000 square feet or less are exempt from the requirements of §110.10.

3.6.3.2 Alterations

The envelope and indoor lighting in the conditioned space of the alteration shall meet the applicable requirements of §110.0 through §130.5 and either one of these:

- The altered envelope, space–conditioning system, lighting and water heating components, and any newly installed equipment serving the alteration, shall meet the applicable requirements of §110.0 through §110.9, §120.0 through §120.6, and §120.8 through §130.5.

  EXCEPTION to §141.0(b)3A: Window Films. Applied window films installed as part of an alteration complies with the U-factor, RSHGC and VT requirements of Table 141.0-E (Table 3-22).

- The standard design for an altered component shall be the higher efficiency of existing conditions or the requirements stated in Table 141.0-E. For components not being altered, the standard design shall be based on the existing conditions. The proposed design shall be based on the actual values of the altered components.

Notes to Alterations – Performance Approach:

1. *If an existing component must be replaced with a new component, that component is considered an altered component for determining the energy budget and must meet the requirements of §141.0(b)3.*
2. *The standard design shall assume the same geometry and orientation as the proposed design.*

3. *The "existing efficiency level" modeling rules, including situations where nameplate data is not available, are described in the ACM Reference Manual.*

Table 3-22: The Standard Design for an Altered Component

Altered Component	Standard Design Without Third Party Verification of Existing Conditions Shall be Based On	Standard Design With Third Party Verification of Existing Conditions Shall be Based On
Roof/Ceiling Insulation, Wall Insulation, and Floor/Soffit Insulation	The requirements of Section 141.0(b)1 and 141.0(b)2Bii.	The requirements of Section 141.0(b)1 and 141.0(b)2Bii.
Fenestration The allowed glass area shall be the small of a. or b. below: a. The proposed glass area; or b. The larger of: 1. The existing glass area that remains; or 2. The area allowed in Section 140.3(a)5A	The U-factor and RSHGC requirements of Table 141.0-A.	The existing U-factor and RSHGC levels.
Space-Conditioning System Equipment and Ducts	The requirements of Sections 141.0(b)2C, Section 141.0(b)2Di or 141.0(b)2Dii, and Section 141.0(b)2E.	The requirements of Sections 141.0(b)2C, Section 141.0(b)2Di or 141.0(b)2Dii, and Section 141.0(b)2E.
Window Film	The U-factor of 0.40 and SHGC value of 0.35.	The existing fenestration in the alteration shall be based on Table 110.6-A and Table 110.6-B.
Service Water Heating Systems	The requirements of Section 140.5 wihtout solar water heating requirements.	The requirements of Section 140.5 wihtout solar water heating requirements.
Roofing Products	The requirements of Section 141.0(b)2B.	The requirements of Section 141.0(b)2B.
Lighting System	The requirements of Sections 141.0(b)2F through 141.0(b)2K.	The requirements of Sections 141.0(b)2F through 141.0(b)2K.
All Other Features	The proposed efficiency levels.	The proposed efficiency levels.

Source: California Energy Commission

Altered Component	Standard Design Without Third-Party Verification of Existing Conditions Shall be Based On	Standard Design with Third-Party Verification of Existing Conditions Shall be Based On
Roof/Ceiling Insulation, Wall Insulation, and Floor/Soffit Insulation	The requirements of §141.0(b)2.	
Fenestration. The allowed glass area shall be the smaller of the a. or b. below: a. The proposed glass area; or b. The larger of: 1.The existing glass area that remains; or 2.The area allowed in §140.3(a)5A.	The U-factor and RSHGC requirements of TABLE 141.0-A.	The existing U-factor and RSHGC levels
Window Film	The U-factor, RSHGC and VT shall be based on TABLE 140.1-A. The existing fenestration in the alteration shall be based on TABLE 110.6-A and Table 110.6-B. Third Party verification not required.	
Roofing Products	The requirements of §141.0(b)2B.	
All Other Measures	The proposed efficiency levels.	

Energy Code, Table 141.0-E

Table of Contents

4 Mechanical Systems

4.1 Overview

The objective of the Building Energy Efficiency Standards (Energy Code) for mechanical systems is to reduce energy consumption while maintaining occupant comfort by:

1. Maximizing equipment efficiency at design conditions and during part load operation
2. Minimizing distribution losses of heating and cooling energy
3. Optimizing system control to minimize unnecessary operation and simultaneous use of heating and cooling energy

An important function of the Energy Code is indoor air quality for occupant comfort and health. The 2022 Standards incorporate requirements for outdoor air ventilation that must be met during normally occupied hours.

This chapter summarizes the requirements for space conditioning, ventilation, and service water heating systems for non-process loads in nonresidential buildings. Chapter 10 covers process loads in nonresidential buildings and spaces.

This chapter is organized as follows:

Section 4.1 overview of the chapter and the scope of the mechanical systems requirement in the Energy Code

Section 4.2 requirements for heating, ventilation, and air conditioning (HVAC) and service water heating equipment efficiency and equipment mounted controls

Section 4.3 mechanical ventilation, natural ventilation, occupant sensor ventilation control, and demand-controlled ventilation

Section 4.4 construction and insulation of ducts and pipes and duct sealing to reduce leakage

Section 4.5 control requirements for HVAC systems including zone controls and controls to limit reheating and recooling

Section 4.6 remaining requirements for HVAC systems, including sizing and equipment selection, load calculations, economizers, electric resistance heating limitation, limitation on air-cooled chillers, fan power consumption, and fan and pump flow controls, dedicated outside air systems, and exhaust air heat recovery.

Section 4.7 remaining requirements for service water heating

Section 4.8 performance method of compliance

Section 4.9 compliance requirements for additions and alterations.

Section 4.10 glossary, reference, and definitions.

Section 4.11 mechanical plan check documents, including information that must be provided in the building plans and specifications to show compliance with the Energy Code

Acceptance requirements apply to all covered systems regardless of whether the prescriptive or performance compliance approach is used.

Chapter 12 lays out the mandated acceptance test requirements, which are summarized at the end of each section.

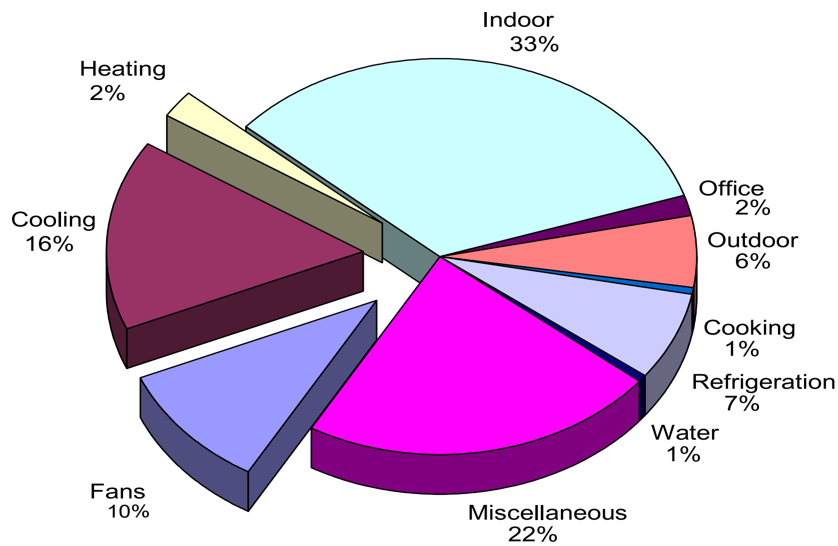
4.1.1 What's New for 2022

- New prescriptive requirements for single zone space conditioning system types for certain space categories (Retail, grocery, school, office, financial institution, and library)
- New prescriptive requirements for heat pump water heating systems for small schools in climate zones 2 through 15
- Adjustments to the VAV airflow deadband controls
- Economizer Changes:
  - Expanded airside economizer requirements
  - New economizer exceptions:
    - Exception for certain dedicated outside air system configurations
    - Exception for controlled environment horticulture using carbon enrichment
- New requirements for Dedicated Outside Air Systems
- Expansion of scope of Occupant Sensor Ventilation Control (Occupied-Standby) to large office spaces
- New requirements for Exhaust Air Heat Recovery
- Changes to the fan power requirements
- Changes to duct leakage testing requirements

4.1.2 HVAC Energy Use

Mechanical and lighting systems are the largest consumers of energy in nonresidential buildings. The amount of energy consumed by various mechanical components varies according to system design and climate. Fans and cooling equipment are the largest components of energy consumed for HVAC purposes in most building in lower elevation climates. Energy consumed for heating is usually less than fans and cooling, followed by service water heating.

Figure 4-1: Typical Nonresidential Building Electricity Us



Heating, cooling and ventilation account for about 28 percent of commercial building electricity use in California.

Source IEQ RFP, December 2002, California Energy Commission No. 500-02-501.

4.1.2.1 Mandatory Measures

Mandatory measures, covered in §110.0-110.12 and §120.0-120.10, apply to all nonresidential buildings, whether the designer chooses the prescriptive or performance approach for compliance. The following sections are applicable to mechanical systems:

1. Equipment certification and equipment efficiency - §110.1 and §110.2
2. Service water heating systems and equipment - §110.3
3. Pool and spa heating systems and equipment - §110.4
4. Restrictions on pilot lights for natural gas appliances and equipment - §110.5
5. Demand responsive controls - §110.12
6. Ventilation and indoor air quality requirements - §120.1
7. Control requirements - §120.2
8. Pipe insulation - §120.3
9. Duct construction, sealing, insulation, and leakage testing - §120.4
10. Acceptance tests in §120.5 and the 2019 Reference Appendices NA7
11. Commissioning - §120.8

12. Commercial Boilers - §120.9
13. Fan Energy Index - §120.10

4.1.3 Prescriptive and Performance Compliance Approaches

The Energy Code allows mechanical system compliance to be demonstrated by meeting the mandatory requirements and the requirements of either the prescriptive or performance compliance approaches.

4.1.3.1 Prescriptive Compliance Approach

- The measures in the prescriptive compliance approach, §140.4, and §140.5, cover specific requirements for individual components and systems that directly comply with the Energy Code, including:

- §140.4(a)1 – Sizing and equipment selection
- §140.4(a)2 – Single zone space conditioning system type
- §140.4 (b) - Load calculations
- §140.4(c) - Fan power consumption
- §140.4(d) - Controls to reduce reheating, recooling and mixing of conditioned air streams
- §140.4(e) - Economizers
- §140.4(f) - Supply temperature reset
- §140.4(g) - Restrictions on electric-resistance heating
- §140.4(h) - Fan speed controls for heat rejection equipment
- §140.4(h) - Limitation on centrifugal fan cooling towers
- §140.4(i) - Minimum chiller efficiency
- §140.4(j) - Limitation on air-cooled chillers
- §140.4(k) - Hydronic system design
- §140.4(m) - Supply fan control
- §140.4(n) - Mechanical system shut-off control
- §140.4(o) - Exhaust system transfer air
- §140.5 – Service Water Heating

4.1.3.2 Performance Compliance Approach

The performance compliance approach, §140.1, allows the designer to trade off energy use between different building systems. This approach provides greater design flexibility but requires extra effort and a computer simulation of the building. The design must still meet all mandatory requirements.

1. Performance approach trade-offs can be applied to the following disciplines: mechanical, lighting, envelope, and covered processes. The performance approach requires creating a proposed energy model using approved Energy Commission compliance software. The software will automatically create a standard design model based on the features of the proposed model and compare the energy use of the two: Standard design energy model that meets mandatory and prescriptive requirements (per the Alternative Calculation Method Reference Manual).
2. Proposed design energy model that reflects the feature of the proposed building.

The proposed model complies if it results in lower time dependent valuation (TDV) energy use than the standard design model.

The performance approach may only be used to model the performance of mechanical systems that are covered under the building permit application (see Section 4.8 and Chapter 11 for more detail).

4.2 Equipment Requirements

All of the equipment efficiency requirements are mandatory measures.

The mandatory requirements for mechanical equipment must be included in the system design, whether the overall building compliance is the prescriptive or performance approach. These features are cost effective over a wide range of building types and mechanical systems.

Most mandatory features for equipment efficiency are requirements for the manufacturer. It is the responsibility of the designer to specify products in the building design that meet these requirements. Manufacturers of central air conditioners and heat pumps, room air conditioners, package terminal air conditioners, package terminal heat pumps, spot air conditioners, computer room air conditioners, central fan-type furnaces, gas space heaters, boilers, pool heaters and water heaters are regulated through the Title 20 Appliance Efficiency Regulations. Manufacturers must certify to the Energy Commission that their equipment meets or exceeds minimum standards. The Commission maintains a database which lists the certified equipment found at: www.energy.ca.gov/appliances/database

Additionally, manufacturers of low leakage air-handling units must certify to the Energy Commission that the air-handler unit meets the specifications in Reference Appendices JA9.

4.2.1 Mandatory Requirements

Mechanical equipment must be certified by the manufacturer as complying with the mandatory requirements in the following sections:

1. §110.0 - Mandatory Requirements for Systems and Equipment Certification
2. §110.1 - Mandatory Requirements for Appliances.
3. §110.2 - Mandatory Requirements for Space-Conditioning Equipment
    a. Efficiency
    b. Gas- and Oil-Fired Furnace Standby Loss Controls
    c. Low Leakage Air-Handling Units
4. §110.3 - Mandatory Requirements for Service Water Heating Systems and Equipment
    a. Certification by Manufactures
    b. Efficiency
5. §110.4 - Mandatory Requirements for Pool and Spa Systems and Equipment
    a. Certification by Manufactures
6. §110.5 - Natural Gas Central Furnaces, Cooking Equipment, and Pool and Spa Heaters: Pilot Lights Prohibited

Mechanical equipment must be specified and installed in accordance with sections:

1. §110.2 - Mandatory Requirements for Space Conditioning Equipment
    a. Controls for Heat Pumps with Supplementary Electric Resistance Heaters
    b. Thermostats
    c. Open and Closed-Circuit Cooling Towers (blowdown control)
2. §110.3 - Mandatory Requirements for Service Water Heating Systems and Equipment
3. §110.12 – Mandatory Requirements for Demand Management
4. §120.1 - Requirements for Ventilation and Indoor Air Quality
5. §120.2 - Required Controls for Space Conditioning Systems (see Section 4.5)
    a. Occupant Controlled Smart Thermostats (OCST)
    b. Direct Digital Controls (DDC)
    c. Optimum Start/Stop Controls
    d. Economizer Fault Detection and Diagnostics
6. §120.3 - Requirements for Pipe Insulation
7. §120.4 - Requirements for Air Distribution Ducts and Plenums
8. §120.5 - Required Nonresidential Mechanical System Acceptance

9. 120.10 – Fan Energy Index

4.2.2 Equipment Efficiency

§110.2(a)

All space conditioning equipment installed in a nonresidential building, subject to these regulations, must be certified as meeting certain minimum efficiency and control requirements. These requirements are contained in §110.2 and vary based on the type and capacity of the equipment. Tables 110.2-A through 110.2-N list the minimum equipment efficiency requirements for the 2022 Energy Code.

Where more than one efficiency standard or test method is listed, the requirements of both shall apply. For example, air-cooled air conditioners have an EER requirement for full-load operation and an IEER for part-load operation. The air conditioner must have both a rated EER and IEER equal to or higher than that specified in the Energy Code at the specified Air-Conditioning, Heating, and Refrigeration Institute (AHRI) standard rating conditions. Where equipment serves more than one function, it must comply with the efficiency standards applicable to each function.

When there is a requirement for equipment rated at its "maximum rated capacity" or "minimum rated capacity," the proper capacity shall be maintained by the controls during steady state operation. For example, a boiler with high/low firing must meet the efficiency requirements when operating at both its maximum capacity and minimum capacity.

Exceptions exist to the listed minimum efficiency for specific equipment. The first exception applies to water-cooled centrifugal water-chilling packages not designed for operation at ANSI/AHRI Standard 550/590 test conditions, which are:

a. 44 degrees Fahrenheit (F) leaving chilled water temperature
b. 85 degrees F entering condenser water temperature
c. Three gallons per minute per ton condenser water flow

Packages not designed to operate at these conditions must have maximum adjusted full load and NPLV ratings, which can be calculated in kW/ton, using Equation 4-1 and Equation 4-2.

Equation 4-1

$$Full\ Load\ Rating_{max,adj} = \frac{(Full\ Load\ Rating)}{K_{adj}}$$

Equation 4-2

$$NPLV\ Rating_{max,adj} = \frac{(IPLV\ Rating)}{K_{adj}}$$

The values for the Full Load and IPLV ratings are found in **Error! Reference source not found.**. K_{adj} is the product of A and B, as in Equation 4-3. A is calculated by entering the value for $LIFT$ determined by Equation 4-5 into the fourth level polynomial in Equation 4-4. B is found using Equation 4-6.

Equation 4-3

$$K_{adj} = A \times B$$

Equation 4-4

$$A = (1.4592 \times 10^{-7})(LIFT^4) - (3.46496 \times 10^{-5})(LIFT^3) + (3.14196 \times 10^{-3})(LIFT^2) - (0.147199)(LIFT) + 3.9302$$

Equation 4-5

$$LIFT = LvgCond - LvgEvap$$

Where:

LvgCond = Full load leaving condenser fluid temperature (°F)

LvgEvap = Full load leaving evaporator fluid temperature (°F)

Equation 4-6

$$B = (0.0015)(LvgEvap) + 0.934$$

Where:

LvgEvap = Full load leaving evaporator fluid temperature (°F)

The maximum adjusted full load and NPLV rating values are only applicable for centrifugal chillers meeting all of the following full-load design ranges:

1. Minimum leaving evaporator fluid temperature: 36 degrees F
2. Maximum leaving condenser fluid temperature: 115 degrees F
3. LIFT greater than or equal to 20 degrees F and less than or equal to 80 degrees F

Centrifugal chillers designed to operate outside of these ranges are not covered by this exception and therefore have no minimum efficiency requirements.

Exception 2 are for positive displacement (air-cooled and water-cooled) chillers with a leaving evaporator fluid temperature higher than 32 degrees F. These equipment shall comply instead with Table 110.2-D in the Energy Code when tested or certified with water at standard rating conditions, per the referenced test procedure.

Exception 3 is for equipment primarily serving refrigerated warehouses or commercial refrigeration systems. These systems must comply with the efficiency requirements of Energy Code §120.6(a) or (b). For more information, see Chapter 10.

4.2.3 Equipment Not Covered by the Appliance Efficiency Regulations

§110.2 and §110.3.

Manufacturers of any appliance or equipment regulated by Section 1601 of the Appliance Efficiency Regulations are required to comply with the certification and testing requirements of Section 1608(a) of those regulations. This includes being listed in the Modernized Appliance Efficiency Database System.

Equipment not covered by the Appliance Efficiency Regulations, for which there is a minimum efficiency requirement in the Energy Code, cannot be installed unless the required efficiency data is listed and verifiable in one of the following:

1. The Energy Commission's database of certified appliances available at: www.energy.ca.gov/appliances/.
2. An equivalent directory published by a federal agency.
3. An approved trade association directory as defined in Title 20 California Code of Regulations, Section 1606(h) such as the Air Conditioning, Heating and Refrigeration Institute (AHRI) Directory of Certified Products. This information is available at www.ahridirectory.org.
4. The Home Ventilating Institute (HVI) certified products directory available at www.hvi.org.

4.2.4 Controls for Heat Pumps With Supplementary Electric Resistance Heaters

§110.2(b)

The Energy Code discourage use of electric resistance heating when an alternative method of heating is available. Heat pumps may contain electric resistance heat strips which act as a supplemental heating source. If this type of system is used, then controls must be put in place to prevent the use of the electric resistance supplementary heating when the heating load can be satisfied with the heat pump alone. The controls must set a cut-on temperature for compressor heating higher than the cut-on temperature for electric resistance heating. The cut-off temperature for compression heating must also be set higher than the cut-off temperature for electric resistance heating.

Exceptions exist for these control requirements if one of the following applies:

1. The electric resistance heating is for defrost and during transient periods such as start-ups and following room thermostat set points (or another control mechanism designed to preclude the unnecessary operation).
2. The heat pump is a room air-conditioner heat pump.

4.2.5 Thermostats

§110.2(c) and §120.2(b)4

All heating or cooling systems are required to have a thermostat with setback capability and is capable of at least four set points in a 24-hour period. In the case of a heat pump, the control requirements of Section 4.2.4 must also be met.

In addition, per §120.2(b)4, the thermostats on all single zone air conditioners and heat pumps must comply with the demand responsive control requirements of Section 110.12(a), also known as the Occupant controlled Smart Thermostat (OCST). See Appendix D of this compliance manual for guidance on compliance with demand responsive control requirements.

Exceptions to §120.2(b)4, setback thermostat and OCST requirements:

1. Systems serving zones that must have constant temperatures to protect a process or product (e.g., a laboratory or a museum).
1. The following HVAC systems are exempt:
    a. Gravity gas wall heaters
    b. Gravity floor heaters
    c. Gravity room heaters
    d. Non-central electric heaters
    e. Fireplaces or decorative gas appliance
    f. Wood stoves
    g. Room air conditioners
    h. Room heat pumps
    i. Packaged terminal air conditioners
    j. Packaged terminal heat pumps

In most cases setup and setback are based on time of day only. However, see Section 4.6.1.4, Shut-off and Temperature Setup/Setback which describes those applications where occupancy sensing is also required to trigger setup and setback periods and shutting off ventilation air.

4.2.6 Furnace Standby Loss Controls

§110.2(d)

Forced air gas- and oil-fired furnaces with input ratings greater than or equal to 225,000 Btu/h are required to have controls and designs that limit their standby losses:

1. Either an intermittent ignition or interrupted device (IID) is required. Standing pilot lights are not allowed.
2. Either a power venting or a flue damper is required. A vent damper is an acceptable alternative to a flue damper for furnaces where combustion air is drawn from the conditioned space.

Any furnace with an input rating greater than or equal to 225,000 Btu/h that is not located within the conditioned space must have jacket losses not exceeding 0.75 percent of the input rating. This includes electric furnaces and fuel-fired units.

4.2.7 Open- and Closed-Circuit Cooling Towers

§110.2 (e)

All open and closed-circuit cooling towers with rated capacity of 150 tons or greater must have a control system that maximizes the cycles of concentration based on the water quality conditions. If the controls system is conductivity based, then the system must automate bleed and chemical feed based on conductivity. The installation criteria for the conductivity controllers must be in accordance with the manufacturer's specifications to maximize accuracy. If the control system is flow based, then the system must be automated in proportion to metered makeup volume, metered bleed volume, and recirculating pump run time (or bleed time).

The makeup water line must be equipped with an analog flow meter and an alarm to prevent overflow of the sump in the event of water valve failure. The alarm system may send an audible signal or an alert through an energy management control system (EMCS).

Drift eliminators are louvered or comb-like devices that are installed at the top of the cooling tower to capture air stream water particles. These drift eliminators are now required to achieve drift reduction to 0.002 percent of the circulated water volume for counter-flow towers and 0.005 percent for crossflow towers.

Additionally, maximum achievable cycles of concentration must be calculated with an Energy Commission approved calculator based on local water quality conditions (which is reported annually by the local utility) and a Langelier Saturation Index (LSI) of 2.5 or less. The maximum cycles of concentration must be cataloged in the mechanical compliance documentation and reviewed and approved by the Professional Engineer (P.E.) of record. Energy Commission compliance document NRCC-MCH-E has a built-in calculator. An approved excel file LSIcalculator is located on the Energy Commission's website.

The website address for the excel calculator is: http://www.energy.ca.gov/title24/2013standards/documents/maximum_cycles_calculator.xls

The website address for the NRCC-MCH-06 is:

http://www.energy.ca.gov/2015publications/CEC-400-2015-033/appendices/forms/NRCC/

4.2.8 Pilot Lights

§110.5

Pilot lights are prohibited in the following circumstances:

3. Fan type central furnaces. This includes all space-conditioning equipment that distributes gas-heated air through duct work §110.5(a). This prohibition does not apply to radiant heaters, unit heaters, boilers or other equipment that does not use a fan to distribute heated air.
4. Household cooking appliances, unless the appliance does not have an electrical connection, and the pilot consumes less than 150 Btu/h §110.5(b).
5. Pool and spa heaters §110.5(c) and §110.5(d) respectively.
6. Indoor and outdoor fireplaces §110.5(e).

Example 4-1

Question

If a 15 ton (180,000 Btu/h) air-cooled packaged AC unit with a gas furnace rated at 260,000 Btu/h maximum heating capacity has an EER of 10.9, an IEER of 12.3, and a heating thermal efficiency of 78 percent, does it comply?

Answer

No. While the cooling side appears to not comply because both the EER and IEER are less than the values listed in Table 4-1, the EER and IEER values in the table are for units with electric heat. Footnote b reduces the required EER and IEER by 0.2 for units with heating sections other than electric resistance heat. Since this unit has gas heat, the EER requirement is actually 10.8 and the IEER requirement is 12.2, this unit complies with the cooling requirements. The 0.2 deduction provided in Table 4-1 and Table 4-2 compensates for the higher fan power required to move air through the heat exchanger.

From Table 4-10, the heating efficiency must be at least 80 percent thermal efficiency. This unit has a 78 percent thermal efficiency and does not comply with the heating requirements; therefore, the entire unit does not comply since it’s a packaged unit.

Example 4-2

Question

A 500,000 Btu/h gas-fired hot water boiler with high/low firing has a full load combustion efficiency of 82 percent, 78 percent thermal efficiency and a low-fire combustion efficiency of 80 percent. Does the unit comply?

Answer

No. Per Table 4-11, the thermal efficiency must be greater than 80 percent. This boiler's thermal efficiency is 78 percent (less than 80 percent), so it doesn't comply.

Example 4-3

Question

A 300-ton water-cooled centrifugal chiller is designed to operate at 44 degrees F chilled water supply, 90 degrees F condenser water return and 3 gpm/ton condenser water flow. What is the maximum allowable full load kW/ton and NPLV?

Answer

As the chiller is centrifugal and is designed to operate at a condition different from AHRI Standard 550/590 standard rating conditions (44 degrees F chilled water supply, 85 degrees F condenser water return, 3 gpm/ton condenser water flow), the appropriate efficiencies can be calculated using the Kadj equations.

From Table 4-4 (Equipment Type: water cooled, electrically operated, centrifugal; Size Category: ≥ 300 tons and < 600 tons), this chiller at AHRI rating conditions is required to have a maximum full load efficiency of 0.560 kW/ton and a maximum IPLV of 0.520 kW/ton for Path A and a maximum full load efficiency of 0.595 kW/ton and a maximum IPLV of 0.390 kW/ton for Path B.

The Kadj is calculated as follows:

LIFT = LvgCond – LvgEvap = 90F-44F = 46F

$A = (0.00000014592 \times (46)^4) - (0.0000346496 \times (46)^3) + (0.00314196 \times (46)^2) - (0.147199 \times (46)) + 3.9302 = 1.08813$

$B = (0.0015 \times 44) + 0.934 = 1.000$

$Kadj = A \times B = 1.08813$

For compliance with Path A, the maximum Full load kW/ton = 0.560 / 1.08813 = 0.515 kW/ton and the maximum NPLV= 0.520 / 1.08813 = 0.478 kW/ton

For compliance with Path B the maximum Full load kW/ton = 0.595 / 1.08813 = 0.547 kW/ton and the maximum NPLV= 0.390 / 1.08813 = 0.358 kW/ton

To meet the mandatory measures of 4.2.2 (Energy Code §110.2) the chiller can comply with either the Path A or Path B requirement (footnote b in Table 4-4). To meet the prescriptive requirement of 4.6.2.8 (Energy Code §140.4(i)) the chiller would have to meet or exceed the Path B requirement.

Example 4-4

Question

A 300 ton water-cooled chiller with a screw compressor that serves a thermal energy storage system is designed to operate at 34 degrees F chilled water supply, 82 degrees F condenser water supply and 94 degrees F condenser water return, does it have a minimum efficiency requirement and if so, what is the maximum full load kW/ton and NPLV?

Answer

As the chiller is positive displacement (screw and scroll compressors are positive displacement) and is designed to operate at a chilled water temperature above 32 degrees F it does have a minimum efficiency requirement per 4.2.2 (Exception 2 to §110.2(a)). From Table 4-4(Equipment Type: water cooled, electrically operated, positive displacement; Size Category: ≥ 300 tons) this chiller at AHRI rating conditions is required to have a maximum full load efficiency of 0.610 kW/ton and a maximum IPLV of 0.520 kW/ton for Path A and a maximum full load efficiency of 0.625 kW/ton and a maximum IPLV of 0.410 kW/ton for Path B.

The Kadj is calculated as follows:

LIFT = LvgCond – LvgEvap = 94F-34F = 60F
A = (0.00000014592 x (60)4) – (0.0000346496 x (60)3)+ (0.00314196 x (60)2) – (0.147199 x *(60)) + 3.9302=0.81613
B = (0.0015 x 34) + 0.934 = 0.98500
Kadj = A x B = 0.80388

For compliance with Path A, the maximum Full load kW/ton = 0.610 / 0.80388 = 0.759 kW/ton and the maximum NPLV= 0.520 / 0.80388 = 0.647 kW/ton. For compliance with Path B the maximum Full load kW/ton = 0.625 / 0.80388 = 0.777 kW/ton and the maximum NPLV= 0.410 / 0.80388 = 0.510 kW/ton. To meet the mandatory measures of 4.2.2 (Energy Code §110.2) the chiller can comply with either the Path A or Path B requirement (footnote b in Table 4-4). To meet the prescriptive requirement of 4.6.2.8 (Energy Code §140.4(i)) the chiller would have to meet or exceed the Path B requirement.

Example 4-5

Question

Are all cooling towers required to be certified by CTI?

Answer

No. Per footnote d in Table 4-7, field-erected cooling towers are not required to be certified. Factory-assembled towers must either be CTI-certified or have their performance verified in a field test (using ATC 105) by a CTI-approved testing agency. Furthermore, only base models need to be tested; options in the airstream, like access platforms or sound traps, will derate the tower capacity by 90 percent of the capacity of the base model or the manufacturer’s stated performance, whichever is less.

Example 4-6

Question

Are there any mandatory requirements for a water-to-water plate-and-frame heat exchanger?

Answer

Yes, Table 4-6 requires that it be rated per ANSI/AHRI 400. This standard ensures the accuracy of the ratings provided by the manufacturer.

4.2.9 Commercial Boilers

§120.9 and §160.4(e)

A commercial boiler is a type of boiler with a capacity (rated maximum input) of 300,000 Btu/h or more and serving a space heating or water heating load in a commercial building.

A. Combustion air positive shut off shall be provided on all newly installed commercial boilers as follows:

1. All boilers with an input capacity of 2.5 MMBtu/h (2,500,000 Btu/h) and above, in which the boiler is designed to operate with a non-positive vent static pressure. This is sometimes referred to as natural draft or atmospheric boilers. Forced draft boilers, which rely on a fan to provide the appropriate amount of air into the combustion chamber, are exempt from this requirement.
2. All boilers where one stack serves two or more boilers with a total combined input capacity per stack of 2.5 MMBtu/h (2,500,000 Btu/h). This requirement applies to natural draft and forced-draft boilers.

Combustion air positive shut off is a means of restricting air flow through a boiler combustion chamber during standby periods and is used to reduce standby heat loss. A flue damper and a vent damper are two examples of combustion air positive shut-off devices.

Installed dampers can be interlocked with the gas valve so that the damper closes and inhibits air flow through the heat transfer surfaces when the burner has cycled off, thus reducing standby losses. Natural draft boilers receive the most benefit from draft dampers because they have less resistance to airflow than forced draft boilers. Forced draft boilers rely on the driving force of the fan to push the combustion gases through an air path that has relatively higher resistance to flow than in a natural draft boiler. Positive shut off on a forced draft boiler is most important on systems with a tall stack height or multiple boiler systems sharing a common stack.

B. Boiler combustion air fans with motors 10 horsepower or larger shall meet one of the following for newly installed boilers:

1. The fan motor shall be driven by a variable speed drive

2. The fan motor shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume

Electricity savings result from run time at part-load conditions. As the boiler firing rate decreases, the combustion air fan speed can be decreased.

C. Newly installed boilers with an input capacity of 5 MMBtu/h (5,000,000 Btu/h) and greater shall maintain stack-gas oxygen concentrations at less than or equal to 5 percent by volume on a dry basis over firing rates of 20 percent to 100 percent. Combustion air volume shall be controlled with respect to firing rate or measured flue gas oxygen concentration. Use of a common gas and combustion air control linkage or jack shaft is prohibited.

Boilers with steady state full-load thermal efficiency of 90 percent or higher are exempt from this requirement.

One way to meet this requirement is with parallel position control. Boilers mix air with fuel (usually natural gas although sometimes diesel or oil) to supply oxygen during combustion. Stoichiometric combustion is the ideal air/fuel ratio where the mixing proportion is correct, the fuel is completely burned, and the oxygen is entirely consumed. Boilers operate most efficiently when the combustion air flow rate is slightly higher than the stoichiometric air-fuel ratio. However, common practice almost always relies on excess air to ensure complete combustion, avoid unburned fuel and potential explosion, and prevent soot and smoke in the exhaust. The drawbacks of excess air are increased stack heat loss and reduced combustion efficiency.

Parallel positioning controls optimize the combustion excess air based on the firing rate of the boiler to improve the combustion efficiency of the boiler. It includes individual servo motors allowing the fuel supply valve and the combustion air damper to operate independently of each other. This system relies on preset fuel mapping (i.e., a pre-programmed combustion curve) to establish proper air damper positions (as a function of the fuel valve position) throughout the full range of burner fire rate. Developing the combustion curve is a manual process. It is performed in the field with a flue-gas analyzer in the exhaust stack, determining the air damper positions as a function of the firing rate/fuel valve position. Depending on the type of burner, a more consistent level of excess oxygen can be achieved with parallel position compared to single-point positioning control with parallel positioning, the combustion curve is developed at multiple points (firing rates), typically 10 to 25 points. Parallel positioning controls allow excess air to remain relatively low throughout a burner's firing range. Maintaining low excess air levels at all firing rates provides significant fuel and cost savings while still maintaining a safe margin of excess air to insure complete combustion.

The other method of control of combustion air volume is by measuring the flue gas oxygen concentration to optimize combustion efficiency. This method of control commonly called is oxygen trim control and can provide higher levels of efficiency than parallel positioning controls based only on firing rate as O_2 trim it can also account for relative humidity of the combustion air. This control strategy relies on parallel positioning hardware and software as the basis but takes it a step further to allow operation closer to stoichiometric conditions. Oxygen trim control converts parallel positioning to a closed-loop control configuration with the addition of an exhaust gas analyzer and proportional-integral-derivative (PID) controller. This strategy continuously measures the oxygen content in the flue gas and adjusts the combustion air flow, thus continually tuning the air-fuel mixture.

D. Gas-fired hot water boiler systems with capacity between 1 and 10 million Btu/h, installed in newly constructed commercial buildings, shall have a weighted thermal efficiency of 90 percent. In order to achieve a thermal efficiency at or over 90 percent, all or some of the boilers must have condensing capability. These high efficiency boilers are referred to as condensing products because they can condense moisture out of flue gas, recovering latent heat from water vapor. Boilers within the same building but on separate loops are not considered to be a part of the same system. Weighted thermal efficiencies are calculated based off the input each boiler provides to the total system capacity.

Boiler systems in Climate Zones 7, 8, and 15 are exempted from this requirement.

Additional requirements for the hot water distribution systems served by these boilers help optimize condensing capabilities.

- First, space heating coils and heat exchangers must be sized so that under design conditions the return temperature of the hot water to the boilers is 120°F or less. Condensing operation requires a sufficient difference in temperatures between the inlet and outlet water.
- Second, hot water space heating systems are designed so that under all conditions the return water entering the boiler(s) must be 120°F or less, or flow rates for supply hot water that recirculates directly into the return system must be no greater than 20 percent of the design flow of the operating boiler. This flow rate requirement increases the likelihood that the boiler system will operate in the condensing range by increasing the amount of time the heating medium, water, contacts the heat exchanger.

There are three exceptions to this condensing requirement. These exceptions remove the following boilers from the thermal efficiency requirements: space heating boilers installed in individual dwelling units, and space heating boilers where 25 percent of the capacity is provided by on-site renewable energy (wind, photovoltaics , solar thermal) or recovered energy (heat recovery chiller, condenser desuperheater, refrigeration heat recovery etc.). Additionally, gas boilers with input capacity of less than 300,000 Btu/h do not need to meet the efficiency requirements and are not included in the calculation of system input or efficiency.

Example 4-6

Question

If I have the following 4 boilers, how do I calculate weighted average thermal efficiency? Boiler 1 with capacity 500,000 Btu/h; Boiler 2 with capacity 600,000 Btu/h and serving an individual dwelling unit; Boiler 3 with capacity 250,000 Btu/h; Boiler 4 with capacity 750,000 Btu/h. Boiler 1 has thermal efficiency of 90%, Boiler 2 has a TE of 87%, Boiler 3 has a TE of 95%, and Boiler 4 has a TE of 95%.

Answer: Since Boiler 2 serves an individual dwelling unit, it is not included in the weighted efficiency calculation. Similarly, since Boiler 3 has a capacity below 300,000 Btu/h, it is not included either. To calculate the weighted average thermal efficiency of boilers 1 and 4, multiply both boilers' thermal efficiency by their capacity, add the two values together, and divide by the combined capacity. So, multiply 90%TE and 500,000 Btu/h and multiply 95%TE and 750,000 Btu/h. Add these two products together and divide by 1,250,000 Btu/h. The result is a weighted thermal efficiency of 93%.

4.3 Fan Energy Index

§120.10

Fan Energy Index (FEI) is a metric that encourages mechanical designers to make fan selections closer to a fan's peak efficiency. The higher the FEI, the less power is consumed at a given duty point (airflow and pressure). FEI is a ratio of the input power of a reference fan and the actual fan at the same duty point.

The requirement applies to fans or fan arrays that exceed a combined motor nameplate horsepower greater than 1.00 hp or a combined fan nameplate electrical input power greater than 0.89 kW.

There are many exceptions to this requirement, primarily intended to exclude fans whose efficiency is regulated by another metric. Exception 1 to Section 120.10(a) covers this category. As Exception 1 states, any embedded fans in equipment listed under Section 110.2, Section 110.1, computer room air conditioners (CRACs) as defined in 10 CFR 431, and dehumidifying direct exchange dedicated outdoor air systems (DX-DOASes) do not need to meet the requirements of 120.10. For example, the supply fan of a commercial unitary air conditioner, which is listed in section 110.2, does not need to meet the requirements of section 120.10.

AMCA 208 defines an embedded fan as "a fan that is set or fixed firmly inside or attached to a surrounding piece of equipment whose purpose exceeds that of a fan or is different than that of a standalone fan. This equipment may have safety or energy efficiency requirements of its own. Examples of embedded fans include supply fans in air handling units, condenser fans in heat rejection equipment, tangential blowers in air curtain units and induced or forced draft combustion blowers in boilers or furnaces."

Other exceptions include embedded fans and embedded fan arrays with a combined motor nameplate horsepower of 5 hp or less or with a fan system electrical input power of 4.1 kW or less (Exception 2), circulation fans, ceiling fans and air curtains (Exception 3), and fans that are intended to only operate during emergency conditions (Exception 4).

For in-scope fans, the requirement is that fans in multi-zone VAV systems must meet an FEI of 0.95 or greater, and all other fans must meet an FEI of 1.0 or greater. The FEI value shall be provided by the manufacturer. For more information about FEI, including how it is calculated, consult with ANSI/AMCA 208.

4.4 Ventilation and Indoor Air Quality Requirements

§120.1 and 160.2

All of the ventilation and indoor air quality requirements are mandatory measures. Some measures require acceptance testing, which is addressed in Chapter 13.

Within a building, all occupied space that is normally used by humans must be continuously ventilated during occupied hours with outdoor air, using either natural or mechanical ventilation as specified in §120.1(c). Ventilation requirements for healthcare facilities should conform to the requirements in Chapter 4 of the California Mechanical Code.

"Spaces normally used by humans" refers to spaces where people can be reasonably expected to remain for an extended period of time. Spaces where occupancy will be brief and intermittent that do not have any unusual sources of air contaminants do not need to be directly ventilated. For example:

- A closet, provided it is not normally occupied
- A storeroom that is only infrequently or briefly occupied. However, a storeroom that can be expected to be occupied for extended periods for clean-up or inventory must be ventilated, preferably with systems controlled by a local switch so that the ventilation system operates only when the space is occupied.

"Continuously ventilated during occupied hours" implies that minimum ventilation must be provided throughout the entire occupied period. Meaning variable air volume (VAV) systems must provide the code-required ventilation over the full range of operating supply airflow. Some means of dynamically controlling the minimum ventilation air must be provided.

4.4.1 Air Filtration

§120.1(c)1 and 160.2(b)1

Occupied spaces may be subjected to poor indoor air quality if poor quality outdoor air is brought in without first being cleaned. Particles less than 2.5 μm are referred to as "fine" particles, and because of their small size, can lodge deeply into the lungs. There is a strong correlation between exposure to fine particles and premature mortality. Other effects of particulate matter exposure include respiratory and cardiovascular disease. Because of these adverse health effects, advances in filtration technology and market availability, removal of fine particulate contaminants by use of filtration is reasonable and achievable. The Energy Code requires that filters have a particle removal efficiency equal to or greater than the minimum efficiency reporting value (MERV) 13 when tested in accordance with ASHRAE Standard 52.2, or a particle size efficiency rating equal to or greater than 50 percent in the 0.3-1.0 μm and 85 percent in the 1.0-3.0 μm range when tested in accordance with AHRI Standard 680.

The following system types are required to provide air filtration:

a. Mechanical space conditioning (heating or cooling) systems that utilize forced air ducts greater than 10 feet in length to supply air to an occupied space. The total is determined by summing the lengths of all the supply and return ducts for the force air system.

b. Mechanical supply-only ventilation systems that provide outside air to an occupied space.

c. The supply side of mechanical balanced ventilation systems, including heat recovery ventilator and energy recovery ventilators that provide outside air to an occupied space.

4.4.1.1 Air Filter Requirements for Space Conditioning Systems and Ventilation Systems in Nonresidential and Hotel/Motel Buildings

Space conditioning systems and ventilation systems in nonresidential and hotel/motel occupancies may use either of the two following compliance approaches:

a. Install a filter grille or accessible filter rack sized by the system designer that accommodates a minimum 2-inch depth filter and install the appropriate filter.

b. Install a filter grille or accessible filter rack that accommodates a minimum 1-inch depth filter and install the appropriate filter. The filter/grille must be sized for a velocity of less than or equal to 150 ft per minute. The installed filter must be labeled to indicate the pressure drop across the filter at the design airflow rate for that return is less than or equal to 0.1-inch w.c. (25 PA).

   Use the following method to calculate the 1 inch per min. This yields a value for the face area in sq ft. Since air filters are sold using nominal sizes in terms of inches, convert the face area to sq in by multiplying the face area (sq ft) by a conversion factor of 144 sq inch/sq ft. Refer also to Equation 4-7 above.

Field verification and diagnostic testing of system airflow in accordance with the procedures in NA1 (HERS verification) is not required for nonresidential and hotel/motel occupancies.

4.4.1.1.1 Energy Code Factors That Affect Air Filter Pressure Drop

Air filter pressure drop can be reduced by increasing the amount of air filter media surface area available to the system's airflow. Increased media surface area can be accomplished by adjusting one, two, or three of the following factors:

a. **Adjust the number of pleats of media per inch inside the air filter frame.** The number of pleats per inch inside the filter frame is determined by the manufacturer's filter model design and is held constant for all filter sizes of the same manufacturer's model. For example, all 3M Filtrete™ 1900 filters will have the same media type, the same MERV rating, and the same number of pleats of media per inch inside the filter frame, regardless of the nominal filter size (20 inches by 30 inches or 24 inches by 24 inches, etc.). Generally, as the number of pleats per inch is increased, the pressure drop is reduced, if all other factors remain constant. The pressure drop characteristics of air filters vary widely between air filter manufacturers and between air filter models, largely due to the number of pleats per inch in the manufacturer's air filter model design. System designers and system owners cannot change the manufacturer's filter model characteristics. They can select a superior air filter model from a manufacturer that provides greater airflow at a lower pressure drop by comparing the filter pressure drop performance shown on the air filter manufacturer's product label (see example label in Figure 4-3).

b. **Adjust the face area of the air filter and filter grille.** Face area is the nominal cross-sectional area of the air filter, perpendicular to the direction of the airflow through the filter. Face area is also the area of the filter grille opening in the ceiling or wall. The face area is determined by multiplying the length times width of the filter face (or filter grille opening). The nominal face area for a filter corresponds to the nominal face area of the filter grille in which the filter is installed. For example, a nominal 20 inch by 30-inch filter has a face area of 600 sq inches and would be installed in a nominal 20 inch by 30-inch filter grille. Generally, as the total system air filter face area increases, the pressure drop is reduced if all other factors remain constant. Total system air filter face area can be increased by specifying a larger area filter/grille, or by using additional/multiple return filters/grilles, summing the face areas. The filter face area is specified by the system designer or installer.

c. **Adjust the depth of the filter and filter grille.** Air filter depth is the nominal filter dimension parallel to the direction of the airflow through the filter. Nominal filter depths readily available for purchase include one, two, four, and six inches. Generally, as the system air filter depth increases, the pressure drop is reduced if all other factors remain constant. For example, increasing filter depth from one inch to two inches nominally doubles the filter media surface area without increasing the filter face area. The filter depth is specified by the system designer or installer.

4.4.1.1.2 Filter Access and Filter Grille Sticker — Design Airflow and Pressure Drop

All filters must be accessible to facilitate replacement.

a. **Air filter grille sticker**. A designer or installer must determine the design airflow rate and maximum allowable clean-filter pressure drop. It must then be posted by the installer on a sticker inside or near the filter grille/rack. The design airflow and initial resistance posted on this sticker should correspond to the conditions used in the system design calculations. This requirement applies to space conditioning systems and also to the ventilation system types described in Sections 4.3.1.1 and 4.3.1.2 above.

   An example of an air filter grille sticker showing the design airflow and pressure drop for the filter grille/rack is shown in Figure 4-2.

b. **Air filter manufacturer label.** Space conditioning system filters are required to be labelled by the manufacturer to indicate the pressure drop across the filter at several airflow rates. The manufacturer's air filter label (see Figure 4-3) must display information that indicates the filter can meet the design airflow rate for that return grille/rack at a pressure drop less than or equal to the value shown on the installer's air filter grille sticker.

Figure 4-2: Example of Installer's Filter Grille Sticker

Air Filter Performance Requirement	Air Filter Performance Requirement	Maintenance Instructions
Airflow Rate (CFM) Must be greater than or equal to the value shown	Initial Resistance (IWC) Must be less than or equal to the value shown	Use only replacement filters that are rated to simultaneously meet both of the performance requirements specified on this sticker.
750	0.1	Use only replacement filters that are rated to simultaneously meet both of the performance requirements specified on this sticker.

Source: California Energy Commission

Figure 4-3: Example Manufacturer's Filter Label Example

MERV	(μm)	0.30-1.0	1.0-3.0	3.0-10	Airflow Rate (CFM)	615	925	1230	1540	2085*	*Max Rated Airflow
13	PSE (%)	62	87	95	Initial Resistance (IWC)	0.07	0.13	0.18	0.25	0.38	

Source: California Energy Commission

4.4.1.1.3 Air Filter Selection

In order for a filter to meet the system's specifications for airflow and pressure drop, it must be rated by the manufacturer to simultaneously provide more than the specified airflow at less than the specified pressure drop. It is unlikely that a filter will be available that is rated to have the exact airflow and pressure drop ratings specified, so filters should be selected that are rated to have less than the specified pressure drop at the specified airflow rate, otherwise select filters that are rated to have greater than the specified airflow rate at the specified pressure drop. See Figure 4-4 for an example of an installer's filter grille sticker that provides an air filter rating specification for minimum airflow of 750 cfm at maximum pressure drop 0.1-inch w.c.

Air filter manufacturers may make supplementary product information available to consumers to assist with selecting the proper replacement filters. This product information may provide more detailed information about their filter model airflow and pressure drop performance - details such as airflow and pressure drop values that are intermediate values that lie between the values shown on their product label. The information may be published in tables, graphs, or presented in software applications available on the internet or at the point of sale.

Figure 4-4 below shows a graphical representation of the initial resistance (pressure drop) and airflow rate ordered pairs given on the example air filter manufacturer's label shown in Figure 4-3 above. The graph in Figure 4-4 makes it possible to visually determine the airflow rate at 0.1-inch w.c. pressure drop for which the values are not shown on the manufacturer's filter label.

If there is no supplementary manufacturer information available and it is necessary to determine a filter model's performance at an airflow rate or pressure drop, linear interpolation may be used. Example formulas for are shown below.

This method may be used to determine an unknown pressure drop corresponding to a known airflow rate by use of Equation 4-8a, or it may also be used to determine an unknown airflow rate corresponding to a known pressure drop by use of Equation 4-8b.

$$\mathbf{p = p_1 + [(f-f_1) \div (f_2-f_1)] \times (p_2 - p_1)} \qquad \text{Equation 4-8a}$$

where:

f = a known flow value between f_1 and f_2

p = the unknown pressure drop value corresponding to f

p_1 and p_2 = known values that are less than and greater than p respectively

f_1 and f_2 are the known values corresponding to p_1 and p_2

$$f = f_1 + [(p - p_1) \div (p_2 - p_1)] \times (f_2 - f_1) \quad \text{Equation 4-8b}$$

where:

p = a <u>known</u> <u>pressure drop</u> value between p_1 and p_2

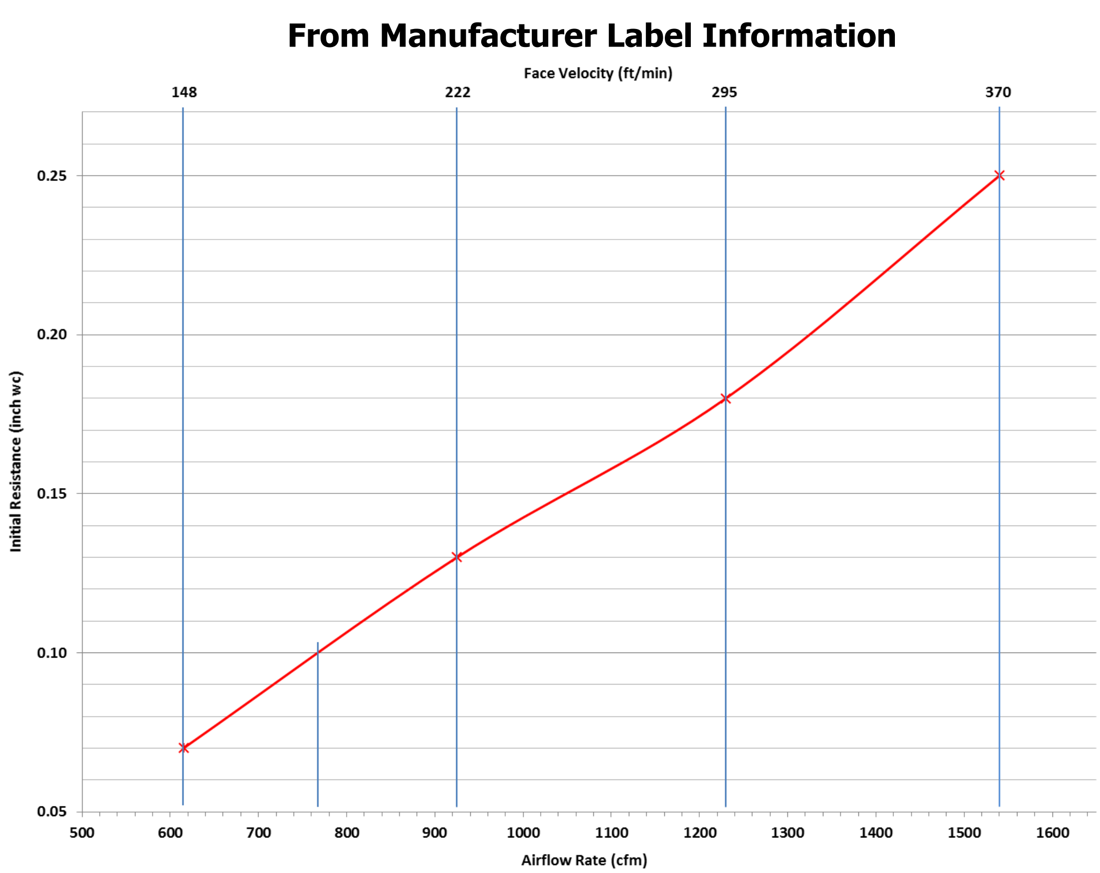
f = the <u>unknown</u> <u>flow</u> value corresponding to p

f_1 and f_2 = known values that are less than and greater than f respectively

p_1 and p_2 are the known values corresponding to f_1 and f_2

See Example 4-7 for sample calculations that determine the filter's rated airflow corresponding to a known pressure drop specification (0.1-inch w.c.).

Figure 4-4: Plot of Pressure Drop vs. Airflow for a 20" X 30" X 1" Depth Air Filter



Source: California Energy Commission

Example 4-7: Filter Selection Using Linear Interpolation

Question

Does the air filter label in Figure 4-3 indicate the filter would meet the airflow (750 cfm) and pressure drop (0.1-inch w.c.) requirements shown on the installer filter grille sticker in figure 4-2? How the airflow rate at 0.1-inch w.c. for the manufacturer's filter label shown in Figure 4-3 be determined?

Answer

The filter must be rated to provide greater than 750 cfm at the specified 0.1-inch w.c. pressure drop, or equivalently: the filter must be rated to provide a pressure drop less than 0.1-inch w.c. at the specified 750 cfm.

Referring to equation 4-8b, calculate the unknown value "f" in cfm that corresponds to the known value "p" of 0.1-inch w.c.

Referring to Figure 4-4: p_1=0.7, p_2=0.13, f_1=615, f_2=925, and applying Equation 4-8b:

615 + [(0.1-0.07) ÷ (0.13-0.07)] x (925-615) yields 770 cfm

Therefore, since the filter is rated for greater than 750 cfm at 0.1-inch w.c., the filter complies.

Example 4-8: Filter Sizing

Question

A 1,200-cfm furnace is being installed in a new dwelling unit. It has a 20" x 20" x 1” inch filter rack furnished with a 1-inch depth filter installed in the unit. Is this filter in compliance?

Answer

The nominal face area of the filter rack is 20 inches by 20 inches to equal 400 sq in and since it is a 1-inch filter, the face area may not be less than 1200 (cfm)/150 (ft/min) x144 (in^2 / ft^2) = 1,152 sq in. Therefore, this filter installation does not comply.

Example 4-9

Question

For the same 1200 cfm furnace, what other options are there?

Answer

The filter will be in compliance if it has a depth of 2” or more and is properly sized by the system designer such that the duct system as a whole will be capable of meeting the HERS verification for fan efficacy specified in Section 150.0(m)13.

Otherwise, the required total system filter face area of 1,152 sq inches must be met using multiple remote wall or ceiling filter grilles for which the sum of the face areas is equal to or greater than 1152 sq inches, and the filters must be rated for pressure drop of 0.1 inch w.c. or less at the design airflow rates of each filter grille.

For any filter, the pressure drop, efficiency, and length of time the filter can remain in operation without becoming fully loaded with dust can all be improved by using filters that are deeper than 1 inch. As the depth of the filter is increased, the pressure drop across the filter at the same face area will be greatly reduced.

Example 4-10

Question

A ductless split system is being installed in a home. Must a designated MERV 13 filter be used?

Answer

No, the filtration requirements do not apply unless there is at least 10 feet of duct is attached to the unit.

Example 4-11

Question

If a customer has allergies and wants a MERV 16 or better filter. Is this in compliance?

Answer

Yes, a filtration greater than MERV 13 meets (exceeds) the minimum particle removal efficiency requirement, thus may be used provided all other applicable requirements in 120.1(b)1 are complied with.

4.4.2 Energy Code requires Natural Ventilation

§120.1(c)2 and §160.2(c)2

The 2019 Energy Code changed the way naturally ventilated spaces are calculated by adopting ASHRAE 62.1. Under these new requirements, naturally ventilated spaces or portions of spaces must be permanently open to and within certain distances of operable wall openings to the outdoors. The space being ventilated, the size of the operable opening and the control of the opening are all considered under these new requirements. Naturally ventilated spaces must also include a mechanical ventilation system that complies with §120.1(c)3 as described in Section 4.3.3., except when the opening to the outdoors is permanently open or has controls that prevent the opening from being closed during periods of expected occupancy. This requirement for mechanical ventilation back-up to a naturally ventilated space protects the occupants from times or events where the outdoor air is not adequate for ventilation and does not rely on an individual to open the opening.

The space to be naturally ventilated is determined based on the configuration of the walls (cross-ventilation, single-sided or adjacent walls) and the ceiling height. For spaces with an operable opening on only one side of the space, only the floor area within two times the ceiling height from the opening is permitted to be naturally ventilated. For spaces with operable openings on two opposite sides of the space, only the floor areas within five times the ceiling height from the openings are permitted to be naturally ventilated. For spaces with operable openings on two adjacent sides of the space (two sides of a corner), only the floor areas along lines connecting the two openings that are within five times the ceiling height meet the requirement. Floor areas not along these lines connecting the windows must meet the one side or two opposite side opening calculation to be permitted to be naturally ventilated. The ceiling height for all of these cases is the minimum ceiling height, except for when the ceiling is sloped upwards from the opening. In that case, the ceiling height is calculated as the average within 20 feet of the opening.

Spaces or portions of space being naturally ventilated must be permanently open to operable walls openings directly to the outdoors. The minimum openable area is required to be 4 percent of the net occupiable floor area being naturally ventilated. Where openings are covered with louvers or otherwise obstructed, the openable area must be based on the free unobstructed area through the opening. Where interior spaces without direct openings to the outdoors are ventilated through adjoining rooms, the opening between rooms must be permanently unobstructed and have a free area of not less than 8 percent of the area of the interior room nor less than 25 sq. ft.

The means to open required operable openings must be readily accessible to building occupants whenever the space is occupied. The operable opening must be monitored to coordinate the operation of the operable opening and the mechanical ventilation system. This is achieved through window contact switches or another type of relay switch that interlocks the operable opening with the mechanical ventilation system. [§140.4(n)]

4.4.3 Mechanical Ventilation

§120.1(c)3 and 160.2(c)3

Mechanical outdoor ventilation must be provided for all spaces normally occupied. The Energy Code requires that a mechanical ventilation system provide outdoor air equal to or exceeding the ventilation rates required for each of the spaces that it serves. At the space, the required ventilation can be provided either directly through supply air or indirectly through transfer of air from the plenum or an adjacent space (see 4.3.6 for updates to transfer air classification). The required minimum ventilation airflow at the space can be provided by an equal quantity of supply or transfer air. At the air-handling unit, the minimum outside air must be the sum of the ventilation requirements of each of the spaces that it serves. The designer may specify higher outside air ventilation rates based on the owner's preference or specific ventilation needs associated with the space. However, specifying more ventilation air than the minimum allowable ventilation rates increases energy consumption and electrical peak demand and increases the costs of operating the HVAC equipment. Thus, the designer should have a compelling reason to specify higher design minimum outside air rates than the calculated minimum outside air requirements.

The minimum outside air (OSA) as measured by acceptance testing, is required to be within 10 percent of the design minimum for both VAV and constant volume units. The design minimum outside air can be no less than the calculated minimum outside air

In summary:

1. Ventilation compliance at the space is satisfied by providing supply and/or transfer air.
2. Ventilation compliance at the air handling system level is satisfied by providing, at minimum, the outdoor air that represents the sum of the ventilation requirements of all the spaces that it serves.

For each space requiring mechanical ventilation the ventilation rates must be either:

1. The conditioned floor area of the space multiplied by the area outdoor air rate (R_a) from Table 4-12. This provides dilution for the building-borne contaminants like off-gassing of paints and carpets, or
2. For spaces designed for an expected number of occupants per the Exception to Section 1004.5 of the CBC, or spaces with fixed seating, the outdoor airflow rate to the zone must be the larger of 15 cfm per person, multiplied by the expected number of occupants or the minimum airflow rate allowed for DCV in Table 4-12, multiplied by the zone floor area. For spaces with fixed seating (such as a theater or auditorium), the expected number of occupants is the number of fixed seats or as determined by the California Building Code.

Table 4-1: Minimum Ventilation Rates

Occupancy Category	Area Outdoor cfm/ Air rate[1] R_a cfm/ft²	Min Air Rate for DCV[2] cfm/ft²	Air Class	Notes
Educational Facilities				
Daycare (through age 4)	0.21	0.15	2	
Daycare sickroom	0.15		3	
Classrooms (ages 5-8)	0.38	0.15	1	
Classrooms (age 9 -18)	0.38	0.15	1	
Lecture/postsecondary classroom	0.38	0.15	1	F
Lecture hall (fixed seats)	-	0.15	1	F
Art classroom	0.15		2	
Science laboratories	0.15		2	
University/college laboratories	0.15		2	
Wood/metal shop	0.15		2	
Computer lab	0.15		1	
Media center	0.15		1	A
Music/theater/dance	1.07*	0.15	1	F
Multiuse assembly	0.50	0.15	1	F
Food and Beverage Service				
Restaurant dining rooms	0.50	0.15	2	
Cafeteria/fast-food dining	0.50	0.15	2	
Bars, cocktail lounges	0.50	0.20	2	
Kitchen (cooking)	0.15		2	
General				
Break rooms	0.50	0.15	1	F
Coffee stations	0.50	0.15	1	F

Occupancy Category	Area Outdoor cfm/ Air rate[1] R_a cfm/ft²	Min Air Rate for DCV[2] cfm/ft²	Air Class	Notes
Conference/meeting	0.50	0.15	1	F
Corridors	0.15		1	F
Occupiable storage rooms for	0.15		2	B
Hotels, Motels, Resorts, Dormitories				
Bedroom/living room	0.15		1	F
Barracks sleeping areas	0.15		1	F
Laundry rooms, central	0.15		2	
Laundry rooms within dwelling	0.15		1	
Lobbies/pre-function	0.50	0.15	1	F
Multipurpose assembly	0.50		1	F

Occupancy Category	Area Outdoor Air Rate[1] R_a cfm /ft²	Min Air Rate for DCV[2] cfm /ft²	Air Class	Notes
Office Buildings				
Breakrooms	0.50	0.15	1	
Main entry lobbies	0.50	0.15	1	F
Occupiable storage rooms for dry	0.15		1	
Office space	0.15		1	F
Reception areas	0.15		1	F
Telephone/data entry	0.15		1	F
Miscellaneous Spaces				
Bank vaults/safe deposit	0.15		2	F
Banks or bank lobbies	0.15		1	F

Occupancy Category	Area Outdoor Air Rate[1] R_a cfm /ft²	Min Air Rate for DCV[2] cfm /ft²	Air Class	Notes
Computer (not printing)	0.15		1	F
Freezer and refrigerated spaces (<50ºF)	-		2	E
General manufacturing (excludes heavy industrial and process using	0.15		3	
Pharmacy (prep. Area)	0.15		2	
Photo studios	0.15		1	
Shipping/receiving	0.15		2	B
Sorting, packing, light assembly	0.15		2	
Telephone closets	0.15		1	
Transportation waiting	0.50	0.15	1	F
Warehouses	0.15		2	B
All others	0.15		2	
Public Assembly Spaces				
Auditorium seating area	1.07	0.15	1	F
Places of religious worship	1.07	0.15	1	F
Courtrooms	0.19	0.15	1	F
Legislative chambers	0.19	0.15	1	F
Libraries (reading rooms and stack areas)	0.15		1	
Lobbies	0.50	0.15	1	F
Museums (children's)	0.25	0.15	1	
Museums/galleries	0.25	0.15	1	F

Occupancy Category	Area Outdoor Air Rate[1] R_a cfm /ft²	Min Air Rate for DCV[2] cfm /ft²	Air Class	Notes
Residential				
Common corridors	0.15		1	F
Retail				
Sales (except as below)	0.25	0.20	2	
Mall common areas	0.25	0.15	1	F
Barbershop	0.40		2	
Beauty and nail salons	0.40		2	
Pet shops (animal areas)	0.25	0.15	2	
Supermarket	0.25	0.20	1	F
Coin-operated laundries	0.30		2	
Sports and Entertainment				
Gym, sports arena (play area)	0.50	0.15	2	E
Spectator areas	0.50	0.15	1	F
Swimming (pool)	0.15		2	C
Swimming (deck)	0.50	0.15	2	C
Disco/dance floors	1.50	0.15	2	F
Health club/aerobics room	0.15		2	
Health club/weight rooms	0.15		2	
Bowling alley (seating)	1.07	0.15	1	
Gambling casinos	0.68	0.15	1	
Game arcades	0.68	0.15	1	
Stages, studios	0.50	0.15	1	D,F

General notes:

1 Ra was determined as being the larger of the area method and the default per person method. The occupant density used in the per person method was assumed to be one half of the maximum occupant load assumed for egress purposes in the California Building Code.

[2]If this column specifies a minimum cfm/ft[2] then it shall be used to comply with Section 120.1(d)4E.

Specific notes:

A – For high-school and college libraries, the values shown for "Public Assembly Spaces – Libraries" shall be used. B – Rate may not be sufficient where stored materials include those having potentially harmful emissions.

C – Rate does not allow for humidity control. "Deck area" refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.

D – Rate does not include special exhaust for stage effects such as dry ice vapors and smoke.

E – Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.

F – Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode

Source: California Energy Commission, 2022 Building Energy Efficiency Standards, Table 120.1-A

As previously stated, each ventilation system must provide outdoor ventilation air as follows:

1. For a ventilation system serving a single space, the required system outdoor airflow is equal to the design outdoor ventilation rate of the space.
2. For a ventilation system serving multiple spaces, the required outdoor air quantity delivered by the system must not be less than the sum of the required outdoor ventilation rate to each space. The Energy Code do not require that each space actually receive its exact calculated outdoor air quantity. Instead, the supply air to any given space may be any combination of recirculated air, outdoor air, or air transferred directly from other spaces, provided:
    a. The total amount of outdoor air delivered by the ventilation system(s) to all spaces is at least as large as the sum of the space design quantities.
    b. Each space always receives supply airflow, including recirculated air and/or transfer air, no less than the calculated outdoor ventilation rate.
    c. When using transfer air, none of the spaces from which air is transferred has any unusual sources of contaminants.

Example 4-9: Ventilation for a Two-Room Building

Question

Consider a building with two spaces, each having an area of 1,000 sq ft. One space is used for general administrative functions, and the other is used as a classroom. It is estimated that the office will contain seven people, and the classroom will contain 50 people (fixed seating). What are the required outdoor ventilation rates?

Answer

1. For the office area, the design outdoor ventilation air is the larger of:

   7 people x 15 cfm/person = 105 cfm; or

   1,000 ft² x 0.15 cfm/ft² = 150 cfm

   For this space, the design ventilation rate is 150 cfm.

2. For the classroom, the design outdoor ventilation air is the larger of:

   50 people x 15 cfm/person = 750 cfm; or

   1,000 ft² x 0.38 cfm/ft² = 380 cfm

   For this space the design ventilation rate is 750 cfm.

Assume the total supply air necessary to satisfy cooling loads is 1,000 cfm for the office and 1,500 cfm for the classroom. If each space is served by a separate system, then the required outdoor ventilation rate of each system is 150 cfm and 750 cfm, respectively. This corresponds to a 15 percent outside air fraction in the office HVAC unit, and 50 percent in the classroom unit.

If both spaces are served by a central system, then the total supply will be (1,000 + 1,500) cfm = 2500 cfm. The required outdoor ventilation rate is (150 + 750) = 900 cfm total. The actual outdoor air ventilation rate for each space is:

Office outside air = 900 cfm x (1,000 cfm / 2,500 cfm) = 360 cfm

Classroom outside air = 900 cfm x (1,500 cfm / 2,500 cfm) = 540 cfm

While this simplistic analysis suggests that the actual outside air cfm to the classroom is less than design (540 cfm vs. 750 cfm), the analysis does not take credit for the dilution effect of the air recirculated from the office. The office is over-ventilated (360 cfm vs. 150 cfm) so the concentration of pollutants in the office return air is low enough that it can be used, along with the 540 cfm of outdoor air, to dilute pollutants in the classroom. The Energy Code allow this design provided that the system always delivers at least 750 cfm to the classroom (including transfer or recirculated air), and that any transfer air is free of unusual contaminants.

4.4.4 Exhaust Ventilation

§120.1(c)4 and §160.2(c)4

The exhaust ventilation requirements are new for the 2019 Energy Code. They are aligned with ASHRAE 62.1 and requires certain occupancy categories to be exhausted to the outdoors, as listed in Table 4-1. Exhaust flow rates must meet or exceed the minimum rates specified in 4-13. The spaces listed are expected to have contaminants not generally found in adjacent occupied spaces. Therefore, the air supplied to the space to replace the air exhausted may be any combination of outdoor air, recirculated air, and transfer air – all of which are expected to have low or zero concentration of the pollutants generated in the listed spaces. For example, the exhaust from a toilet room can draw air from either the outdoors, adjacent spaces, or from a return air duct or plenum. Because these sources of makeup air have essentially zero concentration of toilet-room odors, they are equally good at diluting odors in the toilet room.

The rates specified must be provided during all periods when the space is expected to be occupied, similar to the requirement for ventilation air.

Table 4-2: Minimum Exhaust Rates

Occupancy Category	Exhaust Rate (cfm/unit)	Exhaust Rate (cfm/ft²)	Air Class	Notes
Arenas	-	0.	1	B
Art classrooms	-	0.	2	
Auto repair rooms	-	1.	2	A
Barber shops	-	0.	2	
Beauty and nail salons	-	0.	2	
Cells with toilet	-	1.	2	
Copy, printing rooms	-	0.	2	
Darkrooms	-	1.	2	
Educational science laboratories	-	1.	2	
Janitor closets, trash rooms, recycling	-	1.	3	
Kitchenettes	-	0.	2	
Kitchens – commercial	-	0.	2	
Locker rooms for athletic or industrial facilities	-	0.	2	
All other locker rooms	-	0.	2	
Shower rooms	20/5	-	2	G, H
Paint spray booths	-	-	4	F
Parking garages	-	0.	2	C
Pet shops (animal areas)	-	0.	2	
Refrigerating machinery rooms	-	-	3	F
Soiled laundry storage rooms	-	1.	3	F
Storage rooms, chemical	-	1.	4	F

Occupancy Category	Exhaust Rate (cfm/unit)	Exhaust Rate (cfm/ft²)	Air Class	Notes
Toilets – private	25/5	-	2	E
Toilets – public	50/7	-	2	D
Woodwork shop/classrooms	-	0.	2	

Notes:

A – Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.

B – Where combustion equipment is intended to be used on the playing surface, additional dilution ventilation, source control, or both shall be provided.

C – Exhaust shall not be required where two or more sides comprise walls that are at least 50% open to the outside.

D – Rate is per water closet, urinal, or both. Provide the higher rate where periods of heavy use are expected to occur. The lower rate shall be permitted to be used otherwise.

E – Rate is for a toilet room intended to be occupied by one person at a time. For continuous systems operation during hours of use, the lower rate shall be permitted to be used. Otherwise, the higher rate shall be used.

F – See other applicable standards for exhaust rate.

G – For continuous system operation, the lower rate shall be permitted to be used. Otherwise, the higher rate shall be used.

H – Rate is per showerhead.

Source: California Energy Commission, 2022 Building Energy Efficiency Standards, Table 120.1-B

4.4.5 Air Classification and Recirculation Limitations

§120.1(g) and §160.2(c)8

This section contains air classification, a process that assigns an air class number based on the occupancy category then sets limits on transferring or recirculating that air. This offers designers clear guidance on what can and cannot be used for transfer, makeup, or recirculation air. In the Energy Code, the past, transfer air was allowed as long as it did not have "unusual sources of indoor air contaminants," which left the enforcement of this rule to be arbitrary. Now, all spaces listed in Table 4-12 are assigned an air class and specific direction is given for each class, which is in alignment with ASHRAE 62.1.

Class 1: This class consists of air with low contaminant concentration, low sensory-irritation intensity, and inoffensive odor, suitable for recirculation or transfer to any space. Some examples include classrooms, lecture halls, and lobbies.

Class 2: This class consists of air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odors. Class 2 air is suitable for recirculation or transfer to any space with Class 2 or Class 3 air, and that is utilized for the same or similar purpose and involves the same or similar pollutant sources. Class 2 air may be transferred to toilet rooms and to any Class 4 air occupancies. Class 2 air is not suitable for recirculation or transfer to dissimilar spaces with Class 2 or Class 3 air. It is also not suitable in spaces with Class 1 air, unless the Class 1 space uses an energy recovery device, then recirculation from leakage carryover or transfer from the exhaust side is permitted. In this case the amount of Class 2 air allowed to be transferred or recirculated shall not exceed 10 percent of the outdoor air intake flow. Thus, HVAC systems serving spaces with Class 2 air shall not share the same air handler as spaces with Class 1 air. Some examples include warehouses, restaurants, and auto repair rooms.

Class 3: This class consists of air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor that is suitable for recirculation within the same space. Recirculation of Class 3 air is only permitted within the space of origin. It is not suitable for recirculation or transfer to any other spaces. However, when a space uses an energy recovery device, then recirculation from leakage carryover or transfer from the exhaust side of the energy recovery device is permitted. In this case the amount of Class 3 air allowed to be transferred or recirculated shall not exceed 5 percent of the outdoor air intake flow. HVAC systems serving spaces with Class 3 air shall not share the same air handler serving spaces with Class 1 or Class 2 air. Some examples include general manufacturing (excludes heavy industrial and processes using chemicals) and janitor closets.

Class 4: This class consist of air with highly objectionable fumes or gases, as well as potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Class 4 air is not suitable for recirculation or transfer within the space or to any other space. No leakage of Class 4 air from energy recovery devices is allowed. Some examples include spray paint booths and chemical storage rooms.

In addition to Tables 4-12 and 4-13, the Energy Code also include air classifications for specific airstreams and sources as detailed in Table 4-14. In the event that Tables 4-12, 4-13 and 4-14 do not list the space or location, the air classification of the most similar space listed in terms of occupant activities or building construction shall be used.

Table 4-3: Airstreams or Sources

Description	Air Class
Diazo printing equipment discharge	4
Commercial kitchen grease hoods	4
Commercial kitchen hoods other than grease	3

Description	Air Class
Laboratory hoods	4[a]
Hydraulic elevator machine room	2

a. Air Class 4 unless determined otherwise by the Environmental Health and Safety professional responsible to the owner or to the owner's designee.

Source: California Energy Commission, 2022 Building Energy Efficiency Standards, Table 120.1-C

For ancillary spaces that are designated as Class 1 air but support a Class 2 air space, re-designation of Class 1 air to Class 2 air for ancillary spaces to Class 2 areas is allowed. For example, a bank lobby is designated as Class 1 while bank vaults or safety deposit areas are designated at Class 2. The ancillary space to the bank safety deposit area can be re-designated to Class 2 from Class 1.

4.4.6 Direct Air Transfer

The Energy Code allow air to be directly transferred from one space to another to meet part of the ventilation supply, provided the total outdoor quantity required by all spaces served by the building's ventilation system is supplied by the mechanical systems. This method can be used for any space, but is particularly applicable to conference rooms, toilet rooms, and other rooms that have high ventilation requirements. Transfer air may be a mixture of air from multiple spaces or locations, in which case the air mixture must be classified at the mixed highest classification. Transfer air must meet the requirements of air classification and recirculation limitations, as described above.

Air may be transferred using any method that ensures a positive airflow. Examples include dedicated transfer fans, exhaust fans, and fan powered VAV boxes. A system having a ducted return may be balanced so that air naturally transfers into the space. Exhaust fans serving the space may discharge directly outdoors, or into a return plenum. Transfer systems should be designed to minimize recirculation of transfer air back into the space; duct work should be arranged to separate the transfer air intake and return points.

When each space in a two-space building is served by a separate constant volume system, the calculation and application of ventilation rate is straightforward, and each space will always receive its design outdoor air quantity. However, a central system serving both spaces does not deliver the design outdoor air quantity to each space. Instead, one space receives more than its allotted share, and the other less. This is because some spaces have a higher design outdoor ventilation rate and/or a lower cooling load relative to the other space.

4.4.7 Distribution of Outdoor Air to Zonal Units

§120.1(e) and §160.2(c)6

When a return plenum is used to distribute outside air to a zonal heating or cooling unit, the outside air supply must be connected either:

1. Within 5 ft. of the unit; or
2. Within 15 ft. of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 ft per minute.

Water source heat pumps and fan coils are the most common application of this configuration. The unit fans should be controlled to run continuously during occupancy in order for the ventilation air to be circulated to the occupied space.

Not all spaces are required to have a direct source of outdoor air. Transfer air is allowed from adjacent spaces with direct outdoor air supply if the system supplying the outdoor air is capable of supplying the required outdoor air to all spaces at the same time. Air classification and recirculation limitations will apply, as explained above. An example of an appropriate use of transfer would be in buildings having central interior space-conditioning systems with outdoor air supply, and zonal units on the perimeter without a direct outdoor air supply.

4.4.8 Ventilation System Operation and Controls

§120.1(d)

4.4.8.1 Outdoor Ventilation Air and VAV Systems

Except for systems employing Energy Commission-certified DCV devices or space occupancy sensors, the Energy Code requires that the minimum rate of outdoor air calculated per §120.1(c)3 be provided to each space *at all times,* when the space is normally occupied according to §120.1(d)1. For spaces served by VAV systems, the minimum supply setting of each VAV box should be no less than the design outdoor ventilation rate calculated for the space, unless transfer air is used. If transfer air is used, the minimum box position, plus the transfer air, must meet the minimum ventilation rate.

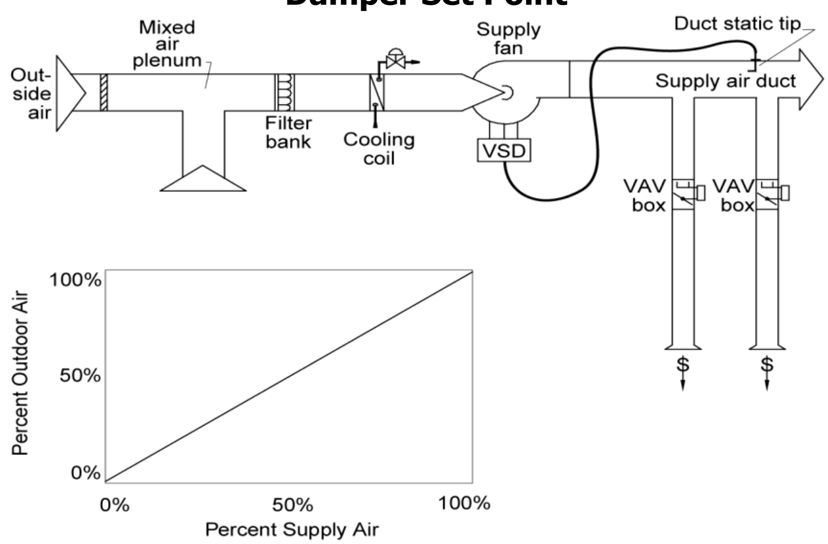
The design outdoor ventilation rate at the system level must always be maintained when the space is occupied, even when the fan has modulated to its minimum capacity §120.1(d)1. Section 4.3.13 describes mandated acceptance test requirements for outside air ventilation in VAV air handling systems where the minimum outside air will be measured at full flow with all boxes at minimum position.

Figure 4-5 shows a typical VAV system. In standard practice, the testing and balancing contractor sets the minimum position setting for the outdoor air damper during construction. It is set under the conditions of design airflow for the system and remains in the same position throughout the full range of system operation, which does not meet code. As the system airflow drops, so will the pressure in the mixed air plenum. A fixed position on the minimum outdoor air damper will produce a varying outdoor airflow. Figure 4-5 shows this effect will be approximately linear (in other words, outdoor air airflow will drop directly in proportion to the supply airflow).

The following paragraphs present several methods used to dynamically control the minimum outdoor air in VAV systems.

Care should be taken to reduce the amount of outdoor air provided when the system is operating during the weekend or after hours with only a fraction of the zones active. Section 120.2(g) requires provision of "isolation zones" of 25,000 sq. ft. or less, which can be accomplished by having the VAV boxes return to fully closed when their associated zone is in unoccupied mode. When a space or group of spaces is returned to occupied mode (e.g., through off-hour scheduling or a janitor's override), only the boxes serving those zones need to be active. During this period when not all the zones are occupied, the ventilation air can be reduced to the required ventilation air of just those zones that are active. If all zones are of the same occupancy type (e.g., private offices), simply assign a floor area to each isolation zone and prorate the minimum ventilation area by the ratio of the sum of the floor areas presently active divided by the sum of all the floor areas served by the HVAC system.

Figure 4-5: VAV Reheat System with a Fixed Minimum Outdoor Air Damper Set Point



A. **Fixed Minimum Damper Set Point**

This method does not comply with the Energy Code. The airflow at a fixed minimum damper position will vary with the pressure in the mixed air plenum. It is explicitly prohibited in §120.1(f)2.

B. **Dual Minimum Set Point Design**

This method complies with the Energy Code. An inexpensive enhancement to the fixed damper set point design is the dual minimum set point design, commonly used on some packaged AC units. The minimum damper position is set proportionally based on fan speed or airflow between a set point determined when the fan is at full speed (or airflow) and minimum speed (or airflow). This method complies with the Energy Code but is not accurate over the entire range of airflow rates or when wind or stack effect pressure fluctuates. With DDC, this design has a relatively low cost.

C. **Energy Balance Method**

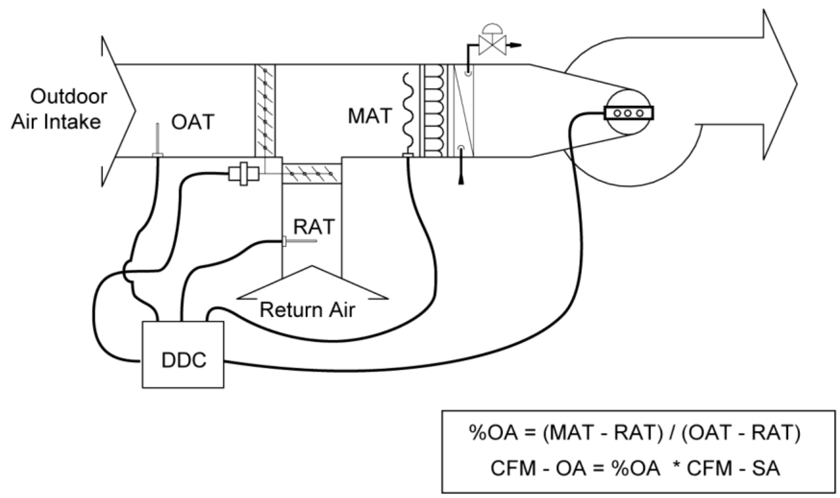
The energy balance method uses temperature sensors located outside, as well as in the return and mixed air plenums to determine the percentage of outdoor air in the supply air stream. The outdoor airflow is then calculated using the equations shown in Figure 4-6. This method requires an airflow monitoring station on the supply fan.

While technically feasible, it may be difficult to meet the outside air acceptance requirements with this approach because:

1. It is difficult to accurately measure the mixed air temperature, which is critical to the success of this strategy. Even with an averaging type of bulb, most mixing plenums have some stratification or horizontal separation between the outside and mixed airstreams.[1]
2. Even with the best installation, high accuracy sensors, and field calibration of the sensors, the equation for percent outdoor air will become inaccurate as the return air temperature approaches the outdoor air temperature. When they are equal, this equation predicts an infinite percentage of outdoor air.
3. The airflow monitoring station is likely to be inaccurate at low supply airflows.
4. The denominator of the calculation amplifies sensor inaccuracy as the return air temperature approaches the outdoor air temperature.

[1] This was the subject of ASHRAE Research Project 1045-RP, "Verifying Mixed Air Damper Temperature and Air Mixing Characteristics." Unless the return is over the outdoor air there are significant problems with stratification or airstream separation in mixing plenums.

Figure 4-6: Energy Balance Method of Controlling Minimum Outdoor Air



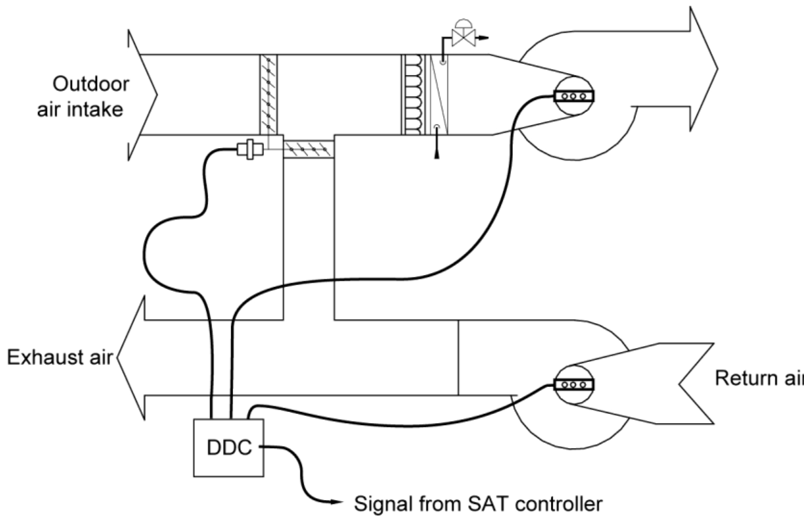
D. **Return Fan Tracking**

This method is also technically feasible but will likely not meet the acceptance requirements because the cumulative error of the two airflow measurements can be large, particularly at low supply/return airflow rates. It only works theoretically when the minimum outdoor air rate equals the rate of air required to maintain building pressurization (the difference between supply air and return air rates). Return fan tracking (Figure 4-7) uses airflow monitoring stations on both the supply and return fans. The theory behind this is that the difference between the supply and return fans should be made up by outdoor air and controlling the flow of return air forces more ventilation into the building. Several problems occur with this method:

1. The relative accuracy of airflow monitoring stations is poor, particularly at low airflows
2. The high cost of airflow monitoring stations
3. Building pressurization problems unless the ventilation air is equal to the desired building exfiltration plus the building exhaust

ASHRAE research has also demonstrated that in some cases this arrangement can cause outdoor air to be drawn into the system through the exhaust dampers due to negative pressures at the return fan discharge.

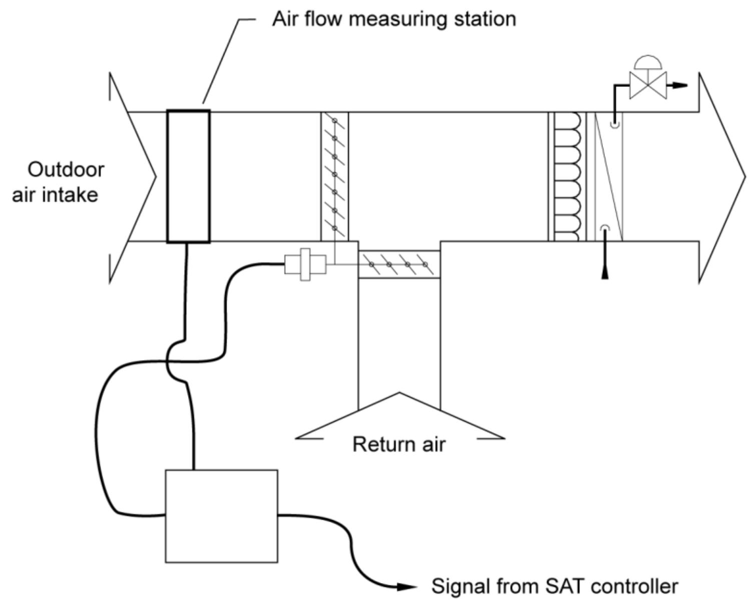
Figure 4-7: Return Fan Tracking



E. Airflow Measurement of the Entire Outdoor Air Inlet

This method is technically feasible but will likely not meet the acceptance requirements, depending on the airflow measurement technology. Most airflow sensors will not be accurate within a 5 to 15 percent turndown (the normal commercial ventilation range). Controlling the outdoor air damper by direct measurement with an airflow monitoring station (Figure 4-8) can be an unreliable method. Its success relies on the turndown accuracy of the airflow monitoring station. Depending on the loads in a building, the ventilation airflow can be between 5 and 15 percent of the design airflow. If the outdoor airflow sensor is sized for the design flow for the airside economizer, this method has to have an airflow monitoring station that can turn down to the minimum ventilation flow (between 5 and 15 percent). Of the different types available, only a hot-wire anemometer array is likely to have this low-flow accuracy while traditional pitot arrays will not. One advantage of this approach is that it provides outdoor airflow readings under all operating conditions, not just when on minimum outdoor air. For highest accuracy, provide a damper and outdoor air sensor for the minimum ventilation air that is separate from the economizer outdoor air intake.

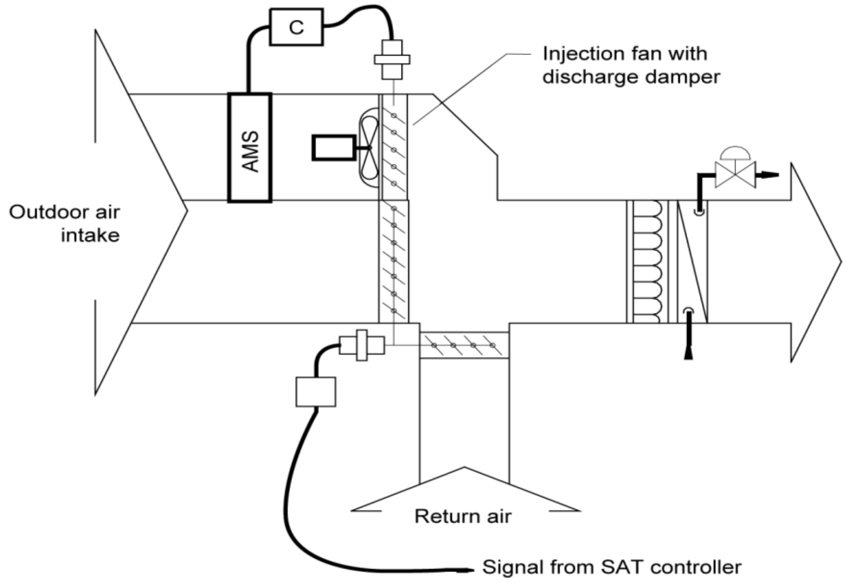
Figure 4-8: Airflow Measurement of 100 Percent Outdoor Air



F. **Injection Fan Method**

This method complies with the Energy Code, but it is expensive and may require additional space. An airflow sensor and damper are required since fan airflow rate will vary, as mixed air plenum pressure varies. The injection fan method (Figure 4-9) uses a separate outdoor air inlet and fan sized for the minimum ventilation airflow. This inlet contains an airflow monitoring station, and a fan with capacity control (e.g., discharge damper; variable frequency drives [VFD]), which is modulated as required to achieve the desired ventilation rate. The discharge damper is required to shut off the intake when the air handling unit (AHU) is off, and also to prevent excess outdoor air intake when the mixed air plenum is significantly negative under peak conditions. The fan is operating against a negative differential pressure and thus cannot stop flow just by slowing or stopping the fan. Though effective, the cost of this method is high and often requires additional space for the injection fan assembly.

Figure 4-9: Injection Fan with Dedicated Minimum Outdoor Air Damper



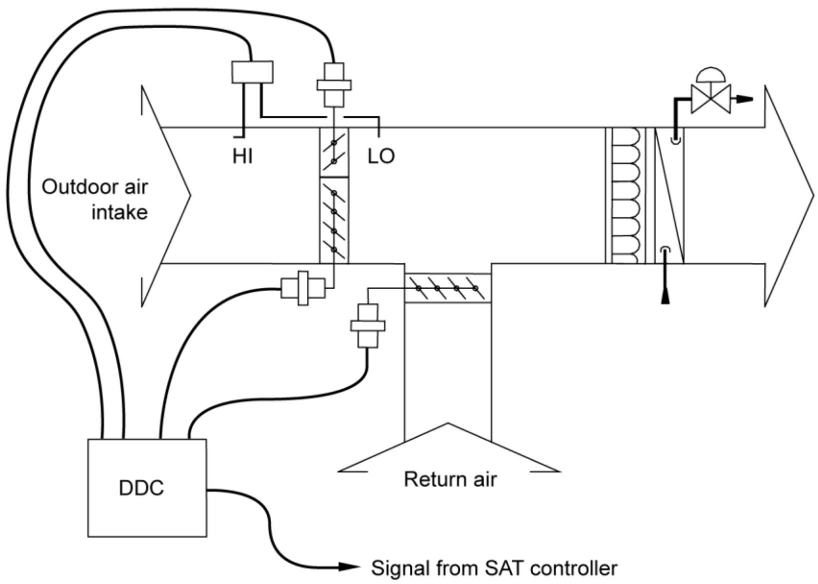
G. Dedicated Minimum Ventilation Damper with Pressure Control

This approach is low cost and takes little space. It can be accurate if the differential set point corresponding to the minimum outdoor air rate is properly set in the field. An inexpensive but effective design uses a minimum ventilation damper with differential pressure control (Figure 4-10). In this method, the economizer damper is broken into two pieces: a small two position damper controlled for minimum ventilation air and a larger, modulating, maximum outdoor air damper that is used in economizer mode. A differential pressure transducer is placed across the minimum outdoor air damper. During start-up, the air balancer opens the minimum outside air (OA) damper and return air damper, closes the economizer OA damper, runs the supply fan at design airflow, measures the OA airflow and adjusts the minimum OA damper position until the OA airflow equals the design minimum OA airflow. The linkages on the minimum OA damper are then adjusted so that the current position is the "full open" actuator position. At this point the design pressure (DP) across the minimum OA damper is measured. This value becomes the DP set point. The principle used here is that airflow is constant across a fixed orifice (the open damper) at fixed DP.

As the supply fan modulates when the economizer is off, the return air damper is controlled to maintain the DP setpoint across the minimum ventilation damper.

The main downside of this method is the complexity of controls and the potential problems determining the DP setpoint in the field. It is often difficult to measure the outdoor air rate due to turbulence and space constraints.

Figure 4-10: Minimum Outdoor Air Damper with Pressure Control



Example 4-10: Minimum VAV cfm

Question

If the minimum required ventilation rate for a space is 150 cfm, what is the minimum allowed airflow for its VAV box when the percentage of outdoor air in the supply air is 20 percent?

Answer

The minimum allowed airflow may be as low as 150 cfm provided that enough outdoor air is supplied to all spaces combined to meet the requirements of §120.1(b)2 for each space individually.

4.4.9 Pre-Occupancy Purge

§120.1(d)2 and §160.2(c)5B

Since many indoor air pollutants are out gassed from the building materials and furnishings, the Energy Code requires that buildings having a scheduled operation be purged before occupancy per §120.1(d)2. Immediately prior to occupancy, outdoor ventilation must be provided in an amount equal to the lesser of:

1. The minimum required ventilation rate for 1 hour
2. Three complete air changes

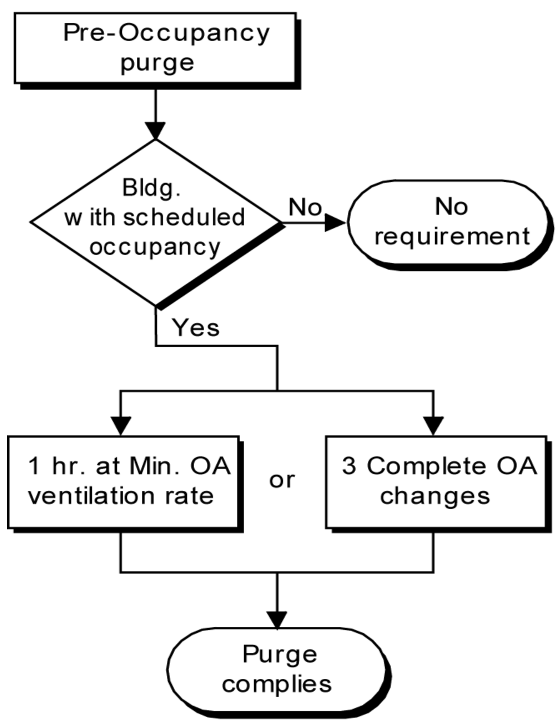
Either criterion can be used to comply with the Energy Code. Three complete air changes mean an amount of ventilation air equal to three times the volume of the occupied space. This air may be introduced at any rate provided for and allowed by the system, so that the actual purge period may be less than an hour.

A pre-occupancy purge is not required for buildings or spaces that are not occupied on a scheduled basis, such as storage rooms. Also, a purge is not required for spaces provided with natural ventilation.

Where pre-occupancy purge is required, it does not have to be coincident with morning warm-up (or cool-down). The simplest way to integrate the two controls is to schedule the system to be occupied one hour prior to the actual time of anticipated occupancy. This allows the optimal start, warm-up, or pull-down routines to bring the spaces up to (or down to) desired temperatures before opening the outdoor air damper for ventilation. This will reduce the required system heating capacity and ensure that the spaces will be at the desired temperatures and fully purged at the start of occupancy.

However, for spaces with occupancy controls which turn ventilation off when occupancy is not sensed, care must be taken in specifying controls and control sequences that the lack of sensed occupancy does not disable or override ventilation during the pre-occupancy purge period.

Figure 4-11: Pre-Occupancy Purge Flowchart



Example 4-11: Purge Period

Question

What is the length of time required to purge a space 10 ft high with an outdoor ventilation rate of 1.5 cfm/sq ft?

Answer

For three air changes, each sq ft of space must be provided with:

OA volume = 3 x 10 = 30 cf/ft²

At a rate of 1.5 cfm/sq ft, the time required is:

Time = 30 cf/ft² / 1.5 cfm/ft² = 20 minutes

Example 4-12: Purge with Natural Ventilation

Question

In a building with natural ventilation, do the windows need to be left open all night to accomplish a building purge?

Answer

No. A building purge is required only for buildings with mechanical ventilation systems.

Example 4-13: Purge with Occupancy Timer

Question

How is a purge accomplished in a building without a regularly scheduled occupancy, whose system operation is controlled by an occupancy sensor?

Answer

This building is most likely 24/7 accessible and a purge requirement would not apply for this building. The occupancy sensors and manual timers can only be used to control ventilation systems in buildings that are intermittently occupied without a predictable schedule.

4.4.10 Demand Controlled Ventilation

§120.1(d)3 and 4 and §160.2(c)5C

Demand controlled ventilation systems reduce the amount of ventilation supply air in response to a measured level of carbon dioxide (CO_2) in the breathing zone. The Energy Code only permit CO_2 sensors for the purpose of meeting this requirement; volatile organic compounds (VOC) and so-called "indoor air quality(IAQ)" sensors are not approved as alternative devices to meet this requirement. The Energy Code only permit DCV systems to vary the ventilation component that corresponds to occupant bioeffluents (this is the basis for the 15 cfm/person portion of the ventilation requirement). The purpose of CO_2 sensors is to track occupancy in a space; however, there are many factors that must be considered when designing a DCV system. There is often a lag time in the detection of occupancy through the build-up of CO_2. This lag time may be increased by any factors that affect mixing, such as short circuiting of supply air or inadequate air circulation, as well as sensor placement and sensor accuracy. Build-up of odors, bioeffluents, and other health concerns may also delay changes in occupancy. Therefore, the designers must be careful to specify CO_2 based DCV systems that are designed to provide adequate ventilation to the space by ensuring proper mixing, avoiding short circuiting, and proper placement and calibration of the sensors.

A. The Energy Code requires the use of DCV systems for spaces. Those that have a design occupancy of 40 sq. ft./person or smaller (for areas without fixed seating where the design density for egress purposes is 40 sq. ft./person or smaller), and has at least one of the following:

1. An air economizer
2. Modulating outside air control
3. Design outdoor airflow rate greater than 3,000 cfm

B. Exceptions to this requirement:

5. The space exhaust is greater than the required ventilation rate minus 0.2 cfm/ft².

   This relates to the fact that spaces with high exhaust requirements won't be able to provide sufficient turndown to justify the cost of the DCV controls. An example of this is a restaurant seating area where the seating area air is used as make-up air for the kitchen hood exhaust.

6. DCV devices are not allowed in spaces that have processes or operations that generate dusts, fumes, mists, vapors, or gases and are not provided with local exhaust ventilation, such as indoor operation of internal combustion engines, areas designated for unvented food service preparation, daycare, sickroom, science lab, barber shop, or beauty and nail salons.

   This exception recognizes that some spaces may need additional ventilation due to contaminants that are not occupant borne. It addresses spaces like theater stages where theatrical fog may be used or movie theater lobbies where unvented popcorn machines may be emitting odors and vapors into the space in either case justifying the need for higher ventilation rates. DCV devices shall not be installed in spaces included in this exception.

7. Spaces with an area of less than 150 sq. ft., or a design occupancy of less than 10 people, per §120.1(c)3 (Table 4-12 above).

   This recognizes the fact that DCV devices may not be cost effective in small spaces such as a 15 ft. by 10 ft. conference room or spaces with only a few occupants at design conditions.

Although not required, the Energy Code permit design professionals to apply DCV on any intermittently occupied spaces served by either single-zone or multiple-zone equipment. §120.1(c)3 requires a minimum of 15 cfm of outdoor air per person multiplied by the expected number of occupants. However, it must be noted that these are minimum ventilation levels, and the designers may specify higher ventilation levels if there are health related concerns that warrant higher ventilation rates.

CO_2 based DCV is based on several studies (Berg-Munch et al. 1986, Cain et al. 1983, Fanger 1983 and 1988, Iwashita et al. 1990, Rasmussen et al. 1985) which concluded that about 15 cfm of outdoor air ventilation per person will control human body odor such that roughly 80 percent of unadapted persons (visitors) will find the odor to be at an acceptable level. As activity level increases and bioeffluents increase, the rate of outdoor air required to provide acceptable air quality increases proportionally, resulting in the same differential CO2 concentration.

A CO_2 sensor only tracks indoor contaminants that are generated by occupants themselves and, to a lesser extent, their activities. It will not track other pollutants, particularly volatile organic compounds that off-gas from furnishings and building materials. Hence, where permitted or required by the Energy Code, DCV systems cannot reduce the outdoor air ventilation rate below the lowest rate listed in Table 4-12 (typically 0.15 cfm/ft²) during normally occupied times.

DCV systems save energy if the occupancy varies significantly over time. Hence, they are most cost effective when applied to densely occupied spaces like auditoriums, conference rooms, lounges, or theaters. Because DCV systems must maintain the lowest ventilation rate listed in Table 4-12, they will not be applicable to sparsely occupied buildings such as offices where the floor rate always exceeds the minimum rate required by the occupants (See Table 4-1).

C. Where DCV is employed (whether mandated or not) the controls must meet all of the following requirements:

1. Sensors must be provided in each room served by the system that has a design occupancy of 40 sq. ft. per person or less, with no less than one sensor per 10,000 sq. ft. of floor space. When a zone or a space is served by more than one sensor, signals from any sensor indicating that CO_2 is near or at the set point within a space, must trigger an increase in ventilation to the space. This requirement ensures that the space is adequately ventilated in case a sensor malfunctions. Design professionals should ensure that sensors are placed throughout a large space, so that all areas are monitored by a sensor.

2. The CO_2 sensors must be located in the breathing zone (between three and six ft. above the floor or at the anticipated height of the occupant's head). Sensors in return air ducts are not allowed since they can result in under-ventilation due to CO_2 measurement error caused by short-circuiting of supply air into return grilles and leakage of outdoor air (or return air from other spaces) into return air ducts.

3. The ventilation must be maintained that will result in a concentration of CO_2 at or below 600 ppm above the ambient level. The ambient levels can either be assumed to be 400 ppm or dynamically measured by a sensor that is

installed within four feet of the outdoor air intake. At 400 ppm outside CO_2 concentration, the resulting DCV CO_2 set point would be 1000 ppm. (A 600-ppm differential is less than the 700 ppm that corresponds to the 15 cfm/person ventilation rate. This provides a margin of safety against sensor error, and because 1000 ppm CO_2 is a commonly recognized guideline value and referenced in earlier versions of ASHRAE Standard 62.) Note that the 1,000 PPM setpoint required by Title 24 is not the same approach to DCV as specified in the current version of ASHRAE 62.1 or ASHRAE 90.1 which do not have a fixed CO2 target for all spaces, and ASHRAE Standards 90.1 and 62.1 have lower ventilation rates per person. ASHRAE Guideline 36-2021, High-Performance Sequences of Operation for HVAC Systems, contains separate sequences of operation for complying with Title 24 and ASHRAE 90.1-2019.

4. Regardless of the CO_2 sensor's reading, the system is not required to provide more than the minimum ventilation rate required by §120.1(c)3. This prevents a faulty sensor reading from causing a system to provide more than the code required ventilation for system without DCV control. This high limit can be implemented in the controls.
5. The system shall always provide a minimum ventilation of the sum of the minimum air rate for DCV for all rooms with DCV and the minimum air rate for all other spaces served by the system, as listed in Table 4-1. This is a low limit setting that must be implemented in the controls.
6. The CO_2 sensors must be factory-certified to have an accuracy within plus or minus 75 ppm at 600 and 1000 ppm concentration when measured at sea level and 25 degree Celsius (77 degrees F), factory calibrated or calibrated at start-up, and certified by the manufacturer to require calibration no more frequently than once every five years. A number of manufacturers now have self-calibrating sensors that either adjust to ambient levels during unoccupied times or adjust to the decrease in sensor bulb output through use of dual sources or dual sensors. For all systems, sensor manufacturers must provide a document to installers that their sensors meet these requirements. The installer must make this certification information available to the builder, building inspectors and, if specific sensors are specified on the plans, to plan checkers.
7. When a sensor failure is detected, the system must provide a signal to reset the system to provide the minimum quantity of outside air levels required by §120.1(c)3 to the zone(s) serviced by the sensor at all times that the zone is occupied. This requirement ensures that the space is adequately ventilated in case a sensor malfunctions. A sensor that provides a high CO_2 signal on sensor failure will comply with this requirement.
8. For systems that are equipped with DDC to the zone level, the CO_2 sensor(s) reading for each zone must be displayed continuously and recorded. The

EMCS may be used to display and record the sensors' readings. The display(s) must be readily available to maintenance staff so they can monitor the systems performance.

4.4.11 Occupant Sensor Ventilation Control Devices

§120.1(d)5 and §160.2(c)5E; §120.3(e)3 and §160.3(a)2Diii

The use of occupant sensor ventilation control devices is mandated for spaces that are also required to use occupant sensing controls to meet the requirements for lighting shut-off controls per §130.1(c), example spaces include offices , multipurpose rooms 1,000 sq. ft. or less, classrooms, conference rooms, and other spaces where the space ventilation is allowed to be reduced to zero in Table 120.1-A (see note F in the right-hand column of the table).

The HVAC system shall be controlled by an occupancy sensing control that resets temperature setpoints and ventilation air in accordance with §120.1(d)5 and §120.2(e)3 when a space meets both the following conditions.

- §130.1(c) items 5,6, and 7 specifies that occupant sensing, as opposed to time-switch, is required to implement shutoff controls.
- Table 120.1-A specifies that ventilation air in the space is allowed to be reduced to zero when the space is in occupied standby mode.

The following table lists all the occupancy categories that meet both conditions above and thus are required to install occupied standby controls if the ventilation zone is serving only qualifying spaces. Note that the "Corridors" category is duplicated from the general category and offices are duplicated from the office category to other building types for clarity.

Table 4-4: Occupancy Categories Qualifying for Occupied Standby Control Requirements

Occupancy Category
Educational Facilities
Lecture/postsecondary classroom
Lecture hall (fixed seats)
Music/theater/dance
Multiuse assembly (only those less than 1,000 square feet)
Corridors
Office Space

Occupancy Category
General
Break rooms (lounges)
Coffee Stations
Conference/meeting
Corridors
Hotels, Motels, Resorts, Dormitories
Common area corridors that provide access to guest rooms
Multipurpose assembly (only those less than 1,000 square feet)
Office Buildings
Office space
Breakrooms (lounges)
Classrooms (professional training rooms)
Conference rooms, multipurpose rooms
Corridors
Telephone/data entry
Residential (based on TABLE 160.2-B)
Multiuse Assembly (only those less than 1,000 square feet)
Break Rooms
Coffee Stations
Conference / Meeting
Corridors
Telephone/data entry

Source: California Energy Commission

Occupant sensor Ventilation control devices are used to implement "occupied standby control." This control is used when the HVAC is scheduled to be ON, but occupancy sensors do not detect any activity in the spaces served by the HVAC zone. During occupied standby, zone temperatures are reset (higher cooling setpoint and lower heating setpoint) and during times when there is neither a call for cooling nor heating the ventilation air is shut off to the zone. When ventilation air is shut off to the zone, the ventilation system serving the zone shall reduce the system outside air by the same amount of outside air reduced at the individual zone. For systems using DOAS units, please see the special note at the end of this section.

Where occupant sensor ventilation control devices are employed (whether mandated or not) the controls must meet all of the following requirements:

1. Sensors must meet the requirements of §110.9(b)4 and shall have suitable coverage to detect occupants in the entire space.
2. Sensors that are used for lighting can be used for ventilation if the ventilation system is controlled directly from the occupant sensor and is not subject to daylighting control or other manual overrides.
3. If a space conditioning system(s) serves several enclosed spaces, each space shall have its own occupant sensor and all sensors must indicate lack of occupancy before the zone airflow is cut off.
4. The occupant sensor override of ventilation shall be disabled during preoccupancy purge (i.e., the terminal unit and central ventilation shall be active regardless of occupant status). Preoccupancy purge occurs during times that are scheduled to be unoccupied and the HVAC system is scheduled off and thus does not overlap with occupied standby periods.
5. Occupant sensing controls shall indicate that a space or lighting zone is vacant in 20 minutes or less after no occupant activity is detected by any occupant sensors covering the space.
6. When all the lighting zones served by the same space conditioning zone are vacant as indicated by the occupant sensing controls, the space conditioning zone enters occupied-standby mode.

   Once a space conditioning zone enters occupied-standby mode, in 5 minutes or less, thermostatic setpoints are reset and mechanical ventilation to the zone shall be shut off until any room served by the space conditioning zone becomes occupied or until ventilation is needed to provide space heating or conditioning. Temperature setback can be achieved either by:

   i. Automatically set up the operating cooling temperature set point by 2°F or more and set back the operating heating temperature set point by 2°F or more; or
   ii. For multiple zone systems with Direct Digital Controls (DDC) to the zone level, set up the operating cooling temperature setpoint by 0.5°F or more and set back the operating heating temperature setpoint by 0.5°F or more.

Note: Steps 5-7 allows a time delay up to 25 minutes (20 minutes sensor time delay + 5 minute occupied standby time delay) after no occupant activity is detected in all lighting zones served by the space conditioning zone and before the ventilation to the rooms is shut off.

The ventilation zone may be serving more than one room, in which case all rooms served by the space conditioning zone must be sensed as unoccupied before the system is placed in occupied standby mode. The illustration below (

Figure 4-12) provides an example of the sequence of events for two rooms (LZ1 and LZ2) served by one ventilation zone and how to occupant-sensing lighting controls relate to the HVAC ventilation controls.

8. Single zone systems when "floating" between a call for heating or cooling will be shut off. For multizone systems with outside airflow monitoring, when the system enters occupied standby and sets the zone airflow to zero, the system outside airflow can be reduced to account for the reduced need for outside air. ASHRAE Guideline 36-2021, *High-Performance Sequences of Operation for HVAC Systems,* provides operating sequences that include the specific instructions for resetting outside air amounts in response to a zone being placed in occupied standby while complying with the Title 24, part 6 minimum outside air flowrates for the other zones.

What is ASHRAE Guideline 36?

ASHRAE Guideline 36, *High-Performance Sequences of Operation for HVAC Systems*, provides peer-reviewed sequences of operation for HVAC systems, written in a format that can be readily implemented by building controls manufacturers and control system contractors. It is continuously updated by a large committee of engineers, manufacturers, scientists, and contractors following the rigorous ASHRAE public review process. These sequences are intended to maximize energy efficiency while maintaining good indoor air quality and comfort. The sequences have been configured and tested to provide control stability and real-time fault detection and diagnostics. Specifying Guideline 36 control sequences reduces risk of Energy Management Control System programming errors and provides a common set of terms and sequences to facilitate communication between specifiers, contractors, and operators.

Example 4-13

Question

If an HVAC zone is designed to serve an office space, conference room, corridor, and restrooms, does this configuration require occupied standby capabilities to shut off ventilation?

Answer

Yes.

Offices Spaces, Corridors, and Restrooms all require occupancy sensing controls under Section 130.1(c) **AND** are occupancy categories that can have their ventilation air reduced to zero when the space is in occupied-standby mode.

- Restrooms require occupant sensing controls under section 130.1(c)5.

- Small offices (250 square feet or less) require occupant sensing controls under 130.1(c)5.

- Large offices (250 square feet or greater) require occupant sensing controls under 130.1(c)6.

- Conference rooms of any size require occupant sensing controls under 130.1(c)5.

- Office Corridors require occupant sensing controls under sections 130.1(c)6.

While restrooms do not have minimum ventilation requirements, restroom ventilation air is pulled from corridors through their minimum exhaust requirements (see "Toilets-public" or "Toilets-private" under Table 120.1-B).

Corridors which provide that ventilation are subject to occupied-standby mode under Table 120.1-A, as are office spaces (as indicated by the note "F" Column).

Below is a limited excerpt from Table 120.1-A, those marked with "F" under the "Notes" column would require occupied standby mode:

Occupancy Category	Air Class	Notes
General	General	General
Break rooms	1	F
Coffee Stations	1	F
Conference/meeting	1	F
Corridors	1	F

Office Buildings	Office Buildings	Office Buildings
Office space	1	F

F – Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied mode.

Example 4--15

Question

If an HVAC zone is designed to serve both an office space and classrooms does this configuration require occupied standby capabilities to shut off ventilation?

Answer

No, for Pre-K and K-12 classrooms.

Yes, for most Higher Education and commercial training classrooms.

As noted in the previous example, the occupied standby mode requirements are triggered if the space is subject to have occupant sensing controls under 130.1(c) **AND** are occupancy categories that can have their ventilation air reduced to zero when the space is in occupied-standby mode under Table 120.1-A. While all classrooms are required occupant sensing controls under Section 130.1(c)5, only certain types of classrooms can reduce ventilation flow to zero when the space is in occupied-standby mode.

In the case of classrooms, pre-K and K-12 educational facilities and some specialized classrooms such as art classrooms do not require occupied standby while those intended for college, community college, business lectures, or classrooms do require them. Note that the space types listed under other building types "Offices" and "General" would still apply to Educational Facilities, as result offices and corridors in educational buildings which both are required to have occupancy sensing and are allowed to set ventilation to 0 during occupied standby would also be required to have occupied standby controls if all the spaces in a thermal zone qualify for occupied standby.

Below is a limited excerpt from Table 120.1-A, those marked with "F" under the "Notes" column require occupied standby mode:

Occupancy Category: Educational Facilities	Air Class	Notes
Classrooms (ages 5-8)	1	
Classrooms (age 9 -18)	1	
Art classroom	2	

Lecture/postsecondary classroom	1	F
Lecture hall (fixed seats)	1	F
Music/theater/dance	1	F
Multiuse assembly	1	F
Occupancy Category: General	Air Class	Notes
Break rooms	1	F
Coffee stations	1	F
Conference meeting rooms	1	F
Corridors	1	F
Occupancy Category: Office	Air Class	Notes
Office space	1	F

F – Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.

Example 4-16

Question 1

For thermal zones required to have occupant sensor ventilation controls, are these spaces allowed to set the ventilation rate to 0 during the preoccupancy ventilation purge period if there are no occupants sensed in the thermal zone?

Answer 1

No. Preoccupancy controls (§120.1[d]), ventilate the building "during the 1-hour period immediately before the building is normally occupied." Occupant sensor control devices (§120.1[d]5E), in contrast operate "When the zone is scheduled to be occupied and occupant sensing controls in all rooms and areas served by the zone indicate the spaces are unoccupied, " To be doubly clear, Section 120.1(d)5D says, "One hour prior to normal scheduled occupancy, occupant sensor ventilation control shall allow pre-occupancy purge as described in Section 120.1(d)2. See

Figure 4-12 even though both spaces are vacant, and lights are out in these spaces, the space is being ventilated during the pre-occupancy purge period. This pre-occupancy purge period ventilated the space prior to the day's scheduled occupancy dilute site generated pollutants that have built up over night.

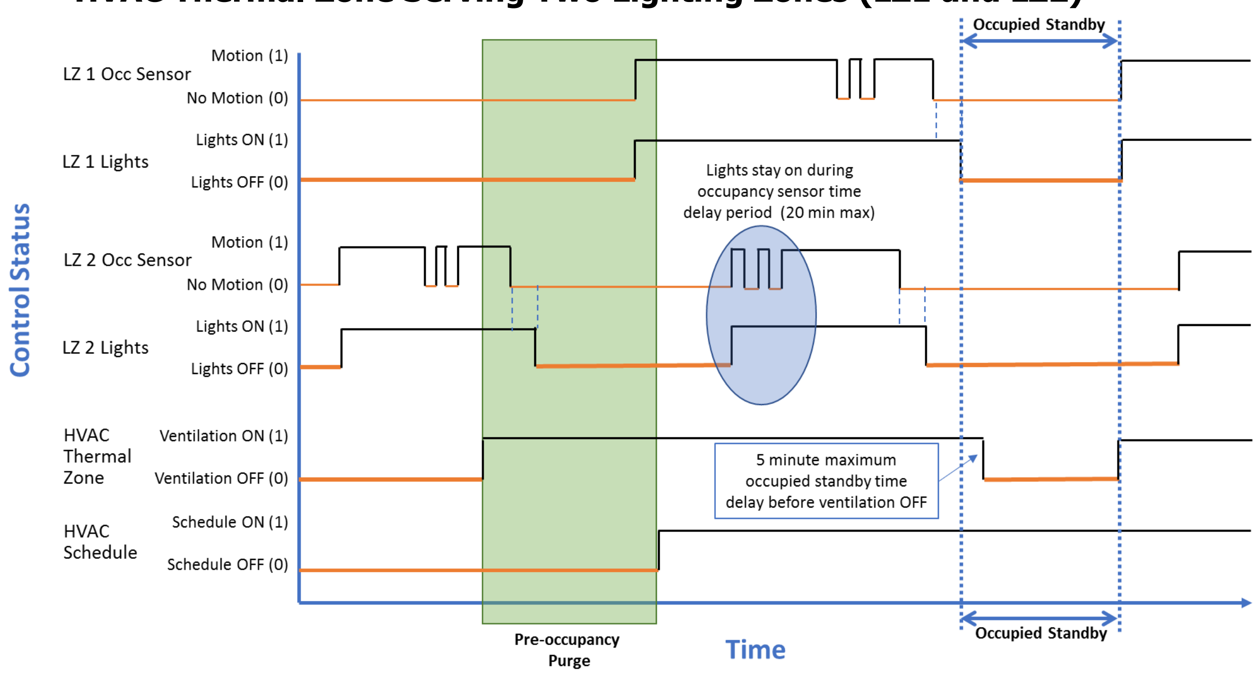
Question 2

For a thermal zone required to have occupant sensor ventilation controls, what is the range of time delays allowed between all occupancy sensors in the zones sensing vacancy and the control shutting off ventilation air to the zone?

Answer 2

Between 0 and 25 minutes. For the control with the shortest time delay, one could directly receive the output of the occupancy sensors and place the system in occupied standby mode whenever all the sensors do not receive a signal indicating occupancy. However, this control would have a lot of false vacancy signals as the occupant sensors are not able to detect movement continuously in occupied spaces and would be cycling the system back and forth between occupied standby and occupied. There are some HVAC designers that directly take the occupant sensor signal without the time delay built into the occupancy sensor and the program the system shut off ventilation air after a 5-minute time delay. It is also acceptable to take the lighting occupant sensor control signal that includes the lighting system time delay which is allowed to be set to as long as 20 minutes. This approach is used when the HVAC control system is taking the on/off signal from an extra set of dry contracts on the lighting occupant sensor. The HVAC system designer is allowed to take this lighting system signal which included the lighting control time delay and add on an extra 5-minute time delay before resetting the system setpoints and shutting off the ventilation air to zero.

Figure 4-12 Control Sequence Diagram of Occupied Standby Control of HVAC Thermal Zone Serving Two Lighting Zones (LZ1 and LZ2)



Source: California Energy Commission

Special Note for Dedicated Outdoor Air Systems (DOAS)

HVAC zones utilizing DOAS units must still adhere to occupied standby control requirements under certain conditions.

For example, if a DOAS unit is used to ventilate multiple spaces without any downstream modulation controls then the entire DOAS unit is treated as one ventilation zone for the purposes of the occupied standby requirement and would only be subject to use occupied-standby controls if **ALL** ventilated spaces were listed under Table 4-4. To comply, the unit would be required to implement occupied standby controls to reduce ventilation to zero (i.e., shut off the DOAS unit) and operate independent of the space-conditioning setpoints.

Additionally, if a DOAS unit features any ventilation modulation controls downstream of the DOAS unit, then any branches of ventilation air with modulation control shall be considered a separate ventilation zone for the purposes of this requirement.

4.4.12 Fan Cycling

§120.1(d)1 and §160.2(c)5A

While §120.1(d)1 requires that ventilation be continuous during normally occupied hours when the space is usually occupied, Exception 2 allows the ventilation to be disrupted for not more than 30 minutes at a time. In this case the ventilation rate during the time the system is ventilating must be increased so the average rate over the hour is equal to the required rate.

It is important to review any related ventilation and fan cycling requirements in Title 8, which is the Division of Occupational Safety and Health (Cal/OSHA) regulations. Section 5142 specifies the operational requirements related to HVAC minimum ventilation. It states:

Operation:

1. The HVAC system shall be maintained and operated to provide at least the quantity of outdoor air required by the State Building Standards Code, Title 24, Part 2, California Administrative Code, in effect at the time the building permit was issued.
2. The HVAC system shall be operated continuously during working hours except:
   a. During scheduled maintenance and emergency repairs.

b. During periods not exceeding a total of 90 hours per calendar year when a serving electric utility by contractual arrangement requests its customers to decrease electrical power demand, or

c. During periods for which the employer can demonstrate that the quantity of outdoor air supplied by nonmechanical means meets the outdoor air supply rate. The employer must have available a record of calculations and/or measurements substantiating that the required outdoor air supply rate is satisfied by infiltration and/or by a nonmechanically driven outdoor air supply system.

d. When a space has entered occupied standby mode as permitted by §120.2(e)3.

Title 8 Section 5142(a)(1) refers to Title 24, Part 2 (the California Building Code) for the minimum ventilation requirements. Section 1203 in the California Building Code specifies the ventilation requirements, but simply refers to the California Mechanical Code, which is Title 24, Part 4.

Chapter 4 in the California Mechanical Code specifies the ventilation requirements. Section 402.3 states, "The system shall operate so that all rooms and spaces are continuously provided with the required ventilation rate while occupied." Section 403.5.1 states, "Ventilation systems shall be designed to be capable of providing the required ventilation rates in the breathing zone whenever the zones served by the system are occupied, including all full and part-load conditions." The required ventilation rates are thus not required whenever the zones are unoccupied. This section affirms that ventilation fans may be turned off during unoccupied periods. In addition, Section 403.6 states, "The system shall be permitted to be designed to vary the design outdoor air intake flow or the space or zone airflow as operating conditions change." This provides further validation to fan cycling as operating conditions change between occupied and unoccupied. A vacant zone has no workers present and is thus not subject to working hour's requirements until the zone is actually occupied by a worker. Finally, Title 24, Part 4, states; "Ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code." Thus, it refers to Title 24, Part 6 as the authority on ventilation.

Title 8 Section 5142(a)(2) states, "The HVAC system shall be operated continuously during working hours." This regulation does not indicate that the airflow, cooling, or heating needs to be continuous. If the HVAC system is designed to maintain average ventilation with a fan cycling algorithm and is active in that mode providing average ventilation air as required during working hours, it is considered to be operating continuously per its mode and sequence. During unoccupied periods, the HVAC system is turned off except for setback and it no longer operates continuously. During the occupied period, occupant sensors or CO_2 sensors in the space provide continuous monitoring and the sequence is operating, cycling the fan and dampers as needed to maintain the ventilation during the occupied period. The

HVAC system is operating with the purpose of providing ventilation, heating, and cooling continuously during the working hours. The heater, air conditioner, fans, and dampers all cycle on and off subject to their system controls to meet the requirements during the working hours.

Exceptions A, B, and C to Title 8 Section 5142(a)(2) all refer to a complete system shutdown where the required ventilation is not maintained.

Example 4-14

Question

Does a single zone air-handling unit serving a 2,000 sq. ft. auditorium with fixed seating for 240 people require DCV?

Answer

Since the space has an occupant load factor of 8.3 sq. ft. per person (2,000 sq. ft. per 240 people), it meets the 40 sq. ft./person or less requirement triggering demand control ventilation if it has at least one of the following:

-Air economizer

-Modulating outside air control -Design outdoor airflow greater than 3,000 cfm

A single CO_2 sensor could be used for this space provided it is certified by the manufacturer to cover 2,000 sq. ft. of space. The sensor must be placed directly in the space.

Example 4--15

Question

If two separate units are used to condition the auditorium in the previous example, is DCV required?

Answer

Yes, for each system that meets the criteria above.

Example 4-16

Question

Does the 2,000 sq ft auditorium in the previous examples require both DCV per Section 4.3.9. and occupant sensor ventilation control devices per Section 4.3.10?

Answer

No, only DCV is required because occupant sensor ventilation control devices are only required for spaces such as offices 250 sq ft or less, multipurpose rooms 1,000 sq ft or less, classrooms, conference rooms, or restrooms.

Example 4--17

Question

If a central AHU supplies five zones of office space (with a design occupant density of 100 sq ft per person and two zones with conference rooms (with a design occupant density of 35 sq ft per person) is it required to have demand-controlled ventilation and if so, on which zones?

Answer

If the AHU has DDC controls to the zone and an airside economizer it is required to have DCV controls in both of the conference room zones.

The minimum OSA will be set for 0.15 cfm/ft² times the total area of all seven zones (the office and conference room zones) and the maximum required OSA does not need to exceed the sum of 0.15 cfm/ft² for the five office zones plus 15 cfm per person for the two conference rooms.

4.4.12.1 Variable Air Volume (VAV) Changeover Systems

Some VAV systems provide conditioned supply air, either heated or cooled, through a single set of ducting. These systems are called VAV changeover systems or, perhaps more commonly, variable volume and temperature (VVT™) systems, named after a control system, distributed by Carrier Corp. In the event that heating is needed in some spaces at the same time that cooling is needed in others, the system must alternate between supplying heated and cooled air. When the supply air is heated, for example, the spaces requiring cooling are isolated (cut off) by the VAV dampers and must wait until the system switches back to cooling mode. In the meantime, they are generally not supplied with ventilation air.

Systems of this type may not meet the ventilation requirements if improperly applied. Where changeover systems span multiple orientations, the designer must make control provisions to ensure that no zone is shut off for more than 30 minutes at a time and that ventilation rates are increased during the remaining time to compensate. Alternatively, minimum damper position or airflow set points can be set for each zone to maintain supply air rates, but this can result in temperature control problems since warm air will be supplied to spaces that require cooling, and vice versa. Changeover systems that are applied to a common building orientation (e.g., all east or all interior) are generally the most successful since zones will usually have similar loads, allowing minimum airflow rates to be maintained without causing temperature control problems.

4.4.13 Adjustment of Ventilation Rate

Section 120.1(c) specifies the minimum required outdoor ventilation rate but does not restrict the maximum. However, if the designer elects to have the space-conditioning system operate at a ventilation rate higher than required by the Energy Code, then the space-conditioning system must be adjustable. This way so the ventilation rate can be reduced in the future to 1) the amount required by the Energy Code, or 2) the rate required for make-up of exhaust systems that are required for a process, for control of odors, or for the removal of contaminants within the space §120.1(f).

In other words, a system can be designed to supply higher than minimum outside air volumes, provided dampers or fan speed can be adjusted to allow no more than the minimum volume if desired in the future. The Energy Code preclude a system designed for 100 percent outdoor air, with no provision for any return air, unless the supply air quantity can be adjusted to be equal to the designed minimum outdoor air volume. The intent is to prevent systems from being designed that will permanently over-ventilate spaces.

4.4.14 Acceptance Requirements

§120.5

The Energy Code has acceptance test requirements for:

1. Ventilation quantities at design airflow for constant volume systems §120.5(a)1 and NA7.5.1.2.
2. Ventilation quantities at design and minimum airflow for VAV systems §120.5(a)1 and NA7.5.1.1.
3. Ventilation system time controls §120.5(a)2 and NA7.5.2.
4. DCV systems §120.5(a)5 and NA7.5.5.

These test requirements are described in Chapter 13 and the Reference Nonresidential Appendix NA7.5. They are described briefly in the following paragraphs.

Example 4--18: Maintenance of Ventilation System

Question

In addition to these commissioning requirements for the ventilation system, are there any periodic requirements for inspection?

Answer

The Energy Code do not contain any such requirements since they apply to the design and commissioning of buildings, not to later operation. However, Section 5142 of the General Industry Safety Orders, Title 8, California Safety Code: Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Building Ventilation, states the following:

Inspection and Maintenance

(1) The HVAC system shall be inspected at least annually, and problems found during these inspections shall be corrected within a reasonable time.

(2) Inspections and maintenance of the HVAC systems shall be documented in writing. The employer shall record the name of the individual(s) inspecting and/or maintaining the system, the date of the inspection and/or maintenance, and the specific findings and actions taken. The employer shall ensure that such records are retained for at least five years.

(3) The employer shall make all records required by this section available for examination and copying, within 48 hours of a request, to any authorized representative of the Division (as defined in Section 3207 of Title 8), to any employee of the employer affected by this section, and to any designated representative of said employee of the employer affected by this Section.

4.4.14.1 Ventilation Airflow

NA7.5.1

Ventilation airflow must be certified to be measured within 10 percent of the design airflow quantities at two points of operation: full design supply airflow (all systems) and (for VAV systems) at airflow with all VAV boxes at or near minimum position. If airflow monitoring stations are provided, they can be used for these measurements.

4.4.14.2 Ventilation System Time Controls and Preoccupancy Purge

NA7.5.2

Programming for preoccupancy purge and HVAC schedules are checked and certified as part of the acceptance requirements. The sequences are also required to be identified by specification section paragraph number (or drawing sheet number) in the compliance documents.

4.4.14.3 Demand-Controlled Ventilation System

NA7.5.5

Demand controlled ventilation systems are checked for compliance with sensor location, calibration (either factory certificate or field validation) and tested for system response with both a high signal (produced by a certified calibration test gas applied to the sensor) and low signal (by increasing the set point above the ambient level). A certificate of acceptance must be provided to the enforcement agency that the demand control ventilation system meets the acceptance requirements for code compliance. The certificate of acceptance must include certification from sensor device manufacturers that their product will meet the requirements of §120.1(d)4F and will provide a signal that indicates the CO_2 level is within range required by §120.1(d)4.; certification from the controls manufacturer that their product responds to the type of signal that the installed sensors supply and can be calibrated to the CO_2 levels specified in §120.1(d)4; and that the CO_2 sensors have an accuracy within plus or minus 75 ppm at 600 and 1,000 ppm concentrations, and require calibration no more frequently than once every five years.

4.5 Pipe and Duct Distribution Systems

4.5.1 Mandatory Measures

4.5.1.1 Requirements for Pipe Insulation

§120.3 and Table 120.3-A, and §160.3(c)1

Most piping conveying mechanically heated or chilled fluids for space conditioning or service water heating must be insulated. The required thickness of piping insulation depends on the temperature of the fluid passing through the pipe, the pipe diameter, the function of the pipe within the system, and the insulation's thermal conductivity.

Table 4-15 specifies the requirements in terms of inches of insulation with conductivity within a specific range. These conductivities are typical for fiberglass or foam pipe insulation. Piping within fan coil units and within other heating or cooling equipment should be insulated based on the pipe diameter and the required value in the table.

Piping that does not require insulation includes the following:

1. Factory installed piping within space-conditioning equipment certified under §110.1 or §110.2, see Section 4.2 of this chapter. Nationally recognized certification programs that are accepted by the Energy Commission for certifying efficiencies of appliances and equipment are considered to meet the requirements for this exception.
2. Piping that conveys fluid with a design operating temperature range between 60 degrees F and 105 degrees F, such as cooling tower piping or piping in water loop heat pump systems.
3. Where the heat gain or heat loss, to or from piping without insulation, will not increase building source energy use. For example, piping connecting fin-tube radiators within the same space would be exempt, as would liquid piping in a split system air conditioning unit.

   This exception would not exempt piping in solar systems. Solar systems typically have backup devices that will operate more frequently if piping losses are not minimized.
4. Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Metal piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing.

Conductivities and thicknesses listed in Table 4-15 are typical for fiberglass and foam. When insulating materials are used that have conductivities different from those listed here for the applicable fluid range, such as calcium silicate, Equation 4-1 may be used to calculate the required insulation thickness.

When a pipe carries cold fluids, condensation of water vapor within the insulation material may impair the effectiveness of the insulation, particularly for applications in very humid environments or for fluid temperatures below 40 degrees F. Examples include refrigerant suction piping and low-temperature thermal energy storage (TES) systems. In these cases, manufacturers should be consulted, and consideration given to low permeability vapor barriers, or closed-cell foams.

The Energy Code also requires that pipe insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

- Insulation exposed to weather shall be installed with a cover suitable for outdoor service. The cover shall be water retardant and provides shielding from solar radiation that can cause degradation of the material. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure. Adhesive tape shall not be used as protection for insulation exposed to weather.

1. Insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall have a Class I or Class II vapor retarder. All penetrations and joints of which shall be sealed.
2. Pipe insulation buried below grade must have a waterproof, uncrushable casing or sleeve. The Energy Code does not define "uncrushability" as any material can be crushed, given enough pressure, and thus it is left to the professional judgement of the designer.

If the conductivity of the proposed insulation does not fall into the conductivity range listed in Table 4-15, the minimum thickness must be adjusted using the following equation:

Equation 4-10: Insulation Thickness

$$T = PR\left[\left(1 + \frac{t}{PR}\right)^{\frac{K}{k}} - 1\right]$$

Where:

T = Minimum insulation thickness for material with conductivity K, inches.

PR = Pipe actual outside radius, inches.

t = Insulation thickness, inches (Table 4-15 for conductivity k).

K = Conductivity of alternate material at the mean rating temperature indicated in Table 4-15 for the applicable fluid temperature range, in Btu-in./(h-ft^2 -°F).

k = The lower value of the conductivity range listed in Table 4-15 for the applicable fluid temperature, Btu-in/(h-ft^2 -°F).

Table 4-15a: Space-Heating and Service Water-Heating Systems Pipe Insulation (thickness in inches)
(Steam, Steam Condensate, Refrigerant, Space Heating, Service Hot Water)

Fluid Operating Temperature Range (°F)	Insulation Conductivity (Btu·in/h·ft²°F)	Insulation Mean Rating Temperature (°F)	Pipe Diameter (in) < 1	Pipe Diameter (in) 1 to <1.5	Pipe Diameter (in) 1.5 to < 4	Pipe Diameter (in) 4 to < 8	Pipe Diameter (in) 8 ≤
Above 350	0.32-0.34	250	4.5	5.0	5.0	5.0	5.0
251-350	0.29-0.32	200	3.0	4.0	4.5	4.5	4.5
201-250	0.27-0.30	150	2.5	2.5	2.5	3.0	3.0
141-200	0.25-0.29	125	1.5	1.5	2.0	2.0	2.0
105-140	0.22-0.28	100	1.0	1.5	1.5	1.5	1.5

Source: Energy Code Table 120.3- A and Table 160.3-D

Table 4-15b: Space-Heating and Service Water-Heating Systems Pipe Insulation (R-Value)
(Steam, Steam Condensate, Refrigerant, Space Heating, Service Hot Water)

Fluid Operating Temperature Range (°F)	Insulation Conductivity (Btu·in/h·ft²°F)	Insulation Mean Rating Temperature (°F)	Pipe Diameter (in) < 1	Pipe Diameter (in) 1 to <1.5	Pipe Diameter (in) 1.5 to < 4	Pipe Diameter (in) 4 to < 8	Pipe Diameter (in) 8 ≤
Above 350	0.32-0.34	250	R 37	R 41	R 37	R 27	R 23
251-350	0.29-0.32	200	R 24	R 34	R 35	R 26	R 22
201-250	0.27-0.30	150	R 21	R 20	R 17.5	R 17	R 14.5
141-200	0.25-0.29	125	R 11.5	R 11	R 14	R 11	R 10
105-140	0.22-0.28	100	R 7.7	R 12.5	R 11	R 9	R 8

Source: Energy Code Table 120.3- A and Table 160.3-D

Table 4-15c: Residential Space-Cooling Systems Pipe Insulation (thickness in inches) (Chilled Water, Refrigerant and Brine)

Fluid Operating Temperature Range (°F)	Insulation Conductivity (Btu·in/h·ft^2°F)	Insulation Mean Rating Temperature (°F)	Pipe Diameter (in) < 1	Pipe Diameter (in) 1 to <1.5	Pipe Diameter (in) 1.5 to < 4	Pipe Diameter (in) 4 to < 8	Pipe Diameter (in) 8 ≤
40-60	0.21-0.27	75	0.75	0.75	1.0	1.0	1.0
Below 40	0.20-0.26	50	1.0	1.5	1.5	1.5	1.5

Source: Energy Code Table 120.3- A and Table 160.3-D

Table 4-15d: Residential Space-Cooling Systems Pipe Insulation (R-Value) (Chilled Water, Refrigerant and Brine)

Fluid Operating Temperature Range (°F)	Insulation Conductivity (Btu·in/h·ft^2°F)	Insulation Mean Rating Temperature (°F)	Pipe Diameter (in) < 1	Pipe Diameter (in) 1 to <1.5	Pipe Diameter (in) 1.5 to < 4	Pipe Diameter (in) 4 to < 8	Pipe Diameter (in) 8 ≤
40-60	0.21-0.27	75	R-6	R-5	R-7	R-6	R-5
Below 40	0.20-0.26	50	R-8.5	R-142	R-12	R-10	R-9

Source: Energy Code Table 120.3- A and Table 160.3-D

Table 4-15e: Nonresidential Space-Cooling Systems Pipe Insulation (thickness in inches) (Chilled Water, Refrigerant and Brine)

Fluid Operating Temperature Range (°F)	Insulation Conductivity (Btu·in/h·ft^2°F)	Insulation Mean Rating Temperature (°F)	Pipe Diameter (in) < 1	Pipe Diameter (in) 1 to <1.5	Pipe Diameter (in) 1.5 to < 4	Pipe Diameter (in) 4 to < 8	Pipe Diameter (in) 8 ≤
40-60	0.21-0.27	75	0.5	0.5	1.0	1.0	1.0
Below 40	0.20-0.26	50	1.0	1.5	1.5	1.5	1.5

Source: Energy Code Table 120.3- A and Table 160.3-D

Table 4-15f: Nonresidential Space-Cooling Systems Pipe Insulation (R-Value) (Chilled Water, Refrigerant and Brine)

Fluid Operating Temperature Range (°F)	Insulation Conductivity (Btu·in/h·ft²°F)	Insulation Mean Rating Temperature (°F)	Pipe Diameter (in) < 1	Pipe Diameter (in) 1 to <1.5	Pipe Diameter (in) 1.5 to < 4	Pipe Diameter (in) 4 to < 8	Pipe Diameter (in) 8 ≤
40-60	0.21-0.27	75	R-3	R-3	R-7	R-6	R-5
Below 40	0.20-0.26	50	R-8.5	R-142	R-12	R-10	R-9

Source: Energy Code Table 120.3-A and Table 160.3-D

Example 4--19

Question

What is the required thickness for calcium silicate insulation on a four-inch diameter pipe carrying a 300-degree F fluid?

Answer

From Table 4-15, using data for 300-degree F fluid:

PR = 2"

t = 4.5" (from the table for a 4-inch pipe with 300-degree F fluid)

K = 0.40 (Btu-in.)/(h-ft²-°F) (from calcium silicate insulation manufacturer's conductivity data at 200-degree F)

k = 0.29 (Btu-in.)/(h-ft²-°F) (the lower value of the range for conductivity for 300-degree F fluid)

$$T = PR[(1 + t/PR)^{K/k} - 1]$$

$$T = 2[(1 + 4.5/2)_{(0.40/0.29)} - 1]$$

T = 8.2 inches

When insulation is not available in the exact thickness calculated, the installed thickness should be the next larger available size.

4.5.1.2 Requirements for Air Distribution System Ducts and Plenums

§120.4 and §160.3(c)2A

Poorly sealed or poorly insulated duct work can cause substantial losses of air volume and energy. All air distribution system ducts and plenums, including building cavities, mechanical closets, air handler boxes and support platforms used as ducts or plenums, are required to be in accordance with the California Mechanical Code Sections 601, 602, 603, 604, 605 and ANSI/SMACNA-006-*2006 HVAC Duct Construction Standards - Metal and Flexible*, 3rd Edition

The 2022 Energy Code requires all ductwork to be sealed to meet Seal Class A. Sealing means the use of adhesives, gaskets, and/or tape systems to close openings in the surface of ductwork and field erected plenums and casings through which air leakage would occur, or the use of continuous welds. Seal Class A means sealing all ductwork connections and applicable duct wall penetrations. Penetrations include pipe, tubing, rods, and wire. Rods that penetrate the duct wall must be allowed to move to function properly (such as a control rod for a volume damper) and should not be sealed in a way that prevents operation. Penetrations do not include screws and other fasteners.

Healthcare facilities are exempt from §120.4 and shall comply with the applicable requirements of the California Mechanical Code.

H. Installation and Insulation

§120.4(a) and §160.3(c)2B

Portions of supply-air and return-air ducts or ductwork conveying heated or cooled air shall be insulated to a minimum installed level of R-8 when installed:

1. Outdoors
2. In a space between the roof and an insulated ceiling
3. In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces
4. In an unconditioned crawlspace
5. In other unconditioned spaces

Portions of supply-air ducts ductwork that are not in one of the above spaces shall be insulated to a minimum installed level of R-4.2 or be exposed in a directly conditioned space. For example, supply-air ducts that are inside the thermal envelope but concealed from view (such as ducts in a chase or above a hard or T-bar ceiling) are required to be insulated with at least R-4.2. However, if the ducts are exposed to directly conditioned space (i.e. ducts are visible to the occupants), then no insulation would be required.

I. Requirements of the California Mechanical Code

1. Mechanically fasten connections between metal ducts and the inner core of flexible ducts.
2. Joint and seal openings with mastic, tape, aerosol sealant or other duct closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B or UL 723 (aerosol sealant).

All joints must be made airtight by use of mastic, tape, aerosol sealant, or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B, or UL 723. Duct systems shall not use cloth-back, rubber adhesive duct tape regardless of UL designation, unless it is installed in combination with mastic and clamps.

When mastic or tape is used to seal openings greater than 1/4 inch, a combination of mastic and mesh or mastic and tape must be used.

The Energy Commission has approved two cloth-backed duct tapes with special butyl or synthetic adhesives rather than rubber adhesive to seal flex duct to fittings. These tapes are:

1. Polyken 558CA or Nashua 558CA, manufactured by Berry Plastics, Tapes and Coatings Division; and
2. Shurtape PC 858CA, manufactured by Shurtape Technologies, Inc.

These tapes passed Lawrence Berkeley National Laboratory tests comparable to those that cloth-back rubber-adhesive duct tapes failed (the Lawrence Berkeley National Laboratory test procedure has been adopted by the American Society of Testing and Materials as ASTM E2342-03). These tapes are allowed to be used to seal flex ducts to fittings without combination with mastic. These tapes cannot be used to seal other duct system joints, such as the attachment of fittings to plenums and junction boxes. On their backing, these tapes have the phrase "CEC Approved," and a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition) to illustrate where they are not allowed to be used. Installation instructions in the box explains how to install the tape on duct core to fittings and a statement that the tape cannot be used to seal fitting to plenum and junction box joints.

J. Factory-Fabricated Duct Systems

§120.4(b)1 and §160.3(c)2Ci

Factory-fabricated duct systems must meet the following requirements:

1. All factory-fabricated duct systems shall comply with UL 181 for ducts and closure systems, including collars, connections, and splices, and be labeled as complying with UL181. UL181 testing may be performed by UL laboratories or a laboratory approved by the Executive Director.
2. Pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts comply with UL 181 and UL181A.
3. Pressure-sensitive tapes and mastics used with flexible ducts comply with UL181 and UL181B.
4. All ductwork and plenums with pressure class ratings shall be constructed to Seal Class A. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Duct located in occupied space and exposed to view is not required to meet Seal Class A.

K. Field-Fabricated Duct Systems

§120.4(b)2 and §160.3(c)2Cii

Field-fabricated duct systems must meet the following requirements:

1. Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems comply with UL 181. Pressure-sensitive tapes, mastics, aerosol sealants or other closure systems shall meet applicable requirements of UL 181, UL 181A and UL 181B.
2. Mastic Sealants and Mesh:

a. Sealants comply with the applicable requirements of UL 181, UL 181A, and UL 181B, and shall be non-toxic and water resistant.

b. Sealants for interior applications shall pass ASTM C 731(extrudability after aging) and D 2202 (slump test on vertical surfaces), incorporated herein by reference.

c. Sealants for exterior applications shall pass ASTM C 731, C 732 (artificial weathering test) and D 2202, incorporated herein by reference.

d. Sealants and meshes shall be rated for exterior use.

3. Pressure-sensitive tapes shall comply with the applicable requirements of UL 181, UL 181A and UL 181B.

4. Drawbands used with flexible duct shall:

   a. Be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties.

   b. Have a minimum tensile strength rating of 150 lbs.

   c. Be tightened as recommended by the manufacturer with an adjustable tensioning tool.

5. Aerosol-Sealant Closures.

   a. Aerosol sealants meet applicable requirements of UL 723 and must be applied according to manufacturer specifications.

   b. Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this section.

6. All ductwork and plenums with pressure class ratings shall be constructed to Seal Class A. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Ductwork located in occupied space and exposed to view is not required to meet Seal Class A.

L. Duct Insulation R-Values

§120.4(c), §120.4(d), §120.4(e) and §160.3(c)2D, E, and Fi

Since 2001, the Energy Code has included the following requirements for the labeling, measurement, and rating of duct insulation:

1. Insulation R-values shall be based on the insulation only and not include air-films or the R-values of other components of the duct system.

2. Insulation R-values shall be tested C-values at 75 degrees F mean temperature at the installed thickness, in accordance with ASTM C 518 or ASTM C 177.
3. The installed thickness of duct insulation for purpose of compliance shall be the nominal thickness for duct board, duct liner, factory made flexible air ducts and factory-made rigid ducts. For factory-made flexible air ducts, the installed thickness shall be determined by dividing the difference between the actual outside diameter and nominal inside diameter by two.
4. The installed thickness of duct insulation for purpose of compliance shall be 75 percent of its nominal thickness for duct wrap.
5. Insulated flexible air ducts must bear labels no further than three feet apart that state the installed R-value (as determined per the requirements of the Energy Code).

A typical duct wrap, nominal 1-1/2 inches and 0.75 pound per cubic foot will have an installed rating of R-4.2 with 25 percent compression.

M. Protection of duct Insulation

§120.4(f) and §160.3(c)2G

The Energy Code requires that exposed duct insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

1. Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure.
2. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

Example 4-20

Question

What are the sealing requirements in a VAV system having a static pressure set point of 1.25 inches water gauge and a plenum return? What are the sealing requirements for exposed ductwork in a utility closet?

Answer

All duct work located within the return plenum must be sealed in accordance with the Seal Class A: all joints, seams, and penetrations must be sealed. A utility closet is not occupied space and therefore exposed ductwork in a utility closet must also be sealed in accordance with Seal Class A. Pressure-sensitive tape heat-seal tape and mastic may be used, if it meets the applicable requirement of UL 181, 181A, 181B, to seal joints and seams which are mechanically fastened per the California Mechanical Code.

G. Duct Sealing and Leakage Testing.

§120.4(g) and §160.3(c)2H

Since 2001, the Energy Code has included prescriptive duct leakage testing for ducts that are part of small single zone systems with portions of the ductwork either outdoors or in uninsulated or vented ceiling spaces. The 2019 California Mechanical Code (CMC) introduced mandatory requirements to seal and test all nonresidential air distribution systems. The prescriptive requirements for duct leakage in the Energy Code were therefore made mandatory and all systems that do not meet the criteria for testing according to the Energy Code are required to meet the requirements in the CMC.

New or replacement duct systems that meet the criteria in 1-4 below shall be sealed to a leakage rate not to exceed 6 percent of the nominal air handler airflow rate as confirmed through HERS field verification and diagnostic testing, in accordance with Reference Nonresidential Appendix NA7.5.3.

1. The duct system does not serve a healthcare facility.
2. The duct system provides conditioned air to an occupiable space for a constant volume, single zone, space-conditioning system.
3. The space conditioning system serves less than 5,000 square feet of conditioned floor area.
4. The combined surface area of the ducts located outdoors or in unconditioned space is more than 25 percent of the total surface area of the entire duct system.

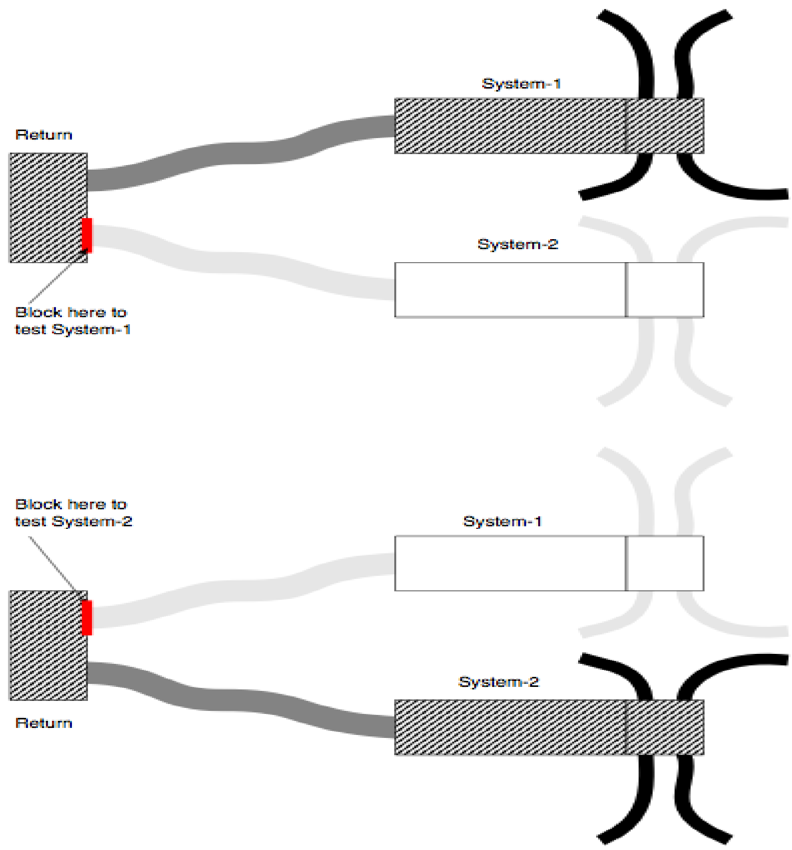
New or replacement duct systems that do not meet the criteria above shall instead meet the duct leakage testing requirements of CMC Section 603.10.1.

Alterations to an existing space conditioning system may trigger the duct sealing requirement. For more information, see Section 4.10.4.2.

A. Duct Leakage Testing for Multiple Duct Systems with Common Return Ducts

If there are two or more duct systems in a building that are tied together at a common return duct, then each duct system should be tested separately, including the shared portion of the return duct system which should be included in each system test. Under this scenario, the portions of the second duct system that is not being tested must be completely isolated from the portions of the ducts that are being tested, so the leakage from the second duct system does not affect the leakage rate from the side that is being tested. The diagram below represents the systems that are attached to a shared return boot or remote return plenum. In this case, the point in the return system that needs to be blocked off is readily accessible through the return grille. The "duct leakage averaging" method where both systems are tested together (as though it is one large system) and the results divided by the combined tonnage to get the target leakage may not be used as it allows a duct system with more the 6 percent leakage to pass if the combined system's leakage is 6 percent or less.

Figure 4-13: Example of Two Duct Systems with a Common Return



Example 4--21

Question

A new 20-ton single zone system with new ductwork serving an auditorium is being installed. Approximately half of its ductwork is on the roof. Does it need to be leak tested in accordance with NA7.5.3 or the California Mechanical Code?

Answer

It likely needs to be tested to the CMC Section 603.10.1. Although this system meets the criteria of being single zone and having more than 25 percent of the duct surface area on the roof, the unit probably serves more than 5,000 sq ft of space. Most 15- and 20-ton units will serve spaces that are significantly larger than 5,000 sq ft. If the space is 5,000 sq ft or less the ducts do need to be leak tested per §120.4(g)1 and NA7.5.3.

Example 4-22

Question

A new 5-ton single zone system with new ductwork serving a 2,000 sq ft office is being installed. The unit is a down discharge configuration and the roof has insulation over the deck. Does the ductwork need to be leak tested in accordance with NA7.5.3 or the California Mechanical Code?

Answer

It likely needs to be tested according to the CMC Section 603.10.1. Although this system meets the criteria of being single zone and serving less than 5,000 sq ft of space, it does not have 25 percent of its duct area outdoors or in unconditioned space. With the insulation on the roof and not on the ceiling, the plenum area likely meets the criteria of indirectly conditioned.

N. Acceptance Requirements

The Energy Code has acceptance requirements where duct sealing and leakage testing is required by §120.5(a)3.

These tests are described in the Chapter 13, Acceptance Requirements, and the Reference Nonresidential Appendix NA7.

4.6 HVAC System Control Requirements

4.6.1 Mandatory Measures

This section covers controls that are mandatory for all system types, including:

- Heat pump controls for the auxiliary heaters
- Zone thermostatic control including special requirements for hotel/motel guest rooms and perimeter systems
- Shut-off and setback/setup controls
- Infiltration control

- Off-hours space isolation
- Economizer fault detection and diagnostics (FDD)
- Control equipment certification
- Direct digital controls (DDC)
- Optimum start/stop controls.

4.6.1.1 Zone Thermostatic Controls

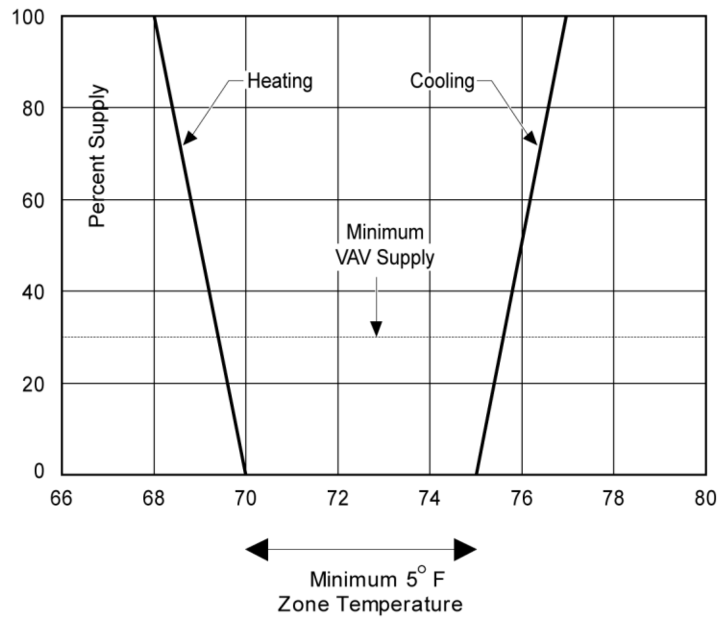
§120.2(a), (b) and (c), and §160.3(a)2A, B, and C

Thermostatic controls must be provided for each space-conditioning zone or dwelling unit to control the supply of heating and cooling energy within that zone. The controls must have the following characteristics:

1. When used to control **heating**, the thermostatic control must be adjustable down to 55 degrees F or lower.
2. When used to control **cooling**, the thermostatic control must be adjustable up to 85 degrees F or higher.
3. When used to control both **heating and cooling**, the thermostatic control must be adjustable from 55 degrees F to 85 degrees F and also provide a temperature range or **dead band** of at least 5 degrees F. When the space temperature is within the dead band, heating and cooling energy must be shut off or reduced to a minimum. A dead band is not required if the thermostat requires a manual changeover between the heating and cooling modes Exception to §120.2(b)*3*.
4. For all single-zone air conditioners and heat pumps, all thermostats shall have setback capabilities with a minimum of four separate set points per 24-hour period. Also, the thermostat must comply with the occupant controlled smart thermostat requirements in §110.12(a), which is capable of responding to demand response signals in the event of grid congestion and shortages during high electrical demand periods.
5. Systems equipped with DDC to the zone level, rather than zone thermostats, must be equipped with automatic demand shed controls that provide demand shedding, as described later in Section 4.6.1.7.

The set point may be adjustable either locally or remotely, by continuous adjustment or by selection of sensors.

Figure 4-14: Proportional Control Zone Thermostat



Supplemental perimeter heating or cooling systems are sometimes used to augment a space-conditioning system serving both interior and perimeter zones. This is allowed provided controls are incorporated to prevent the two systems from conflicting with each other. If that were the case, then the Energy Code requires that:

1. The perimeter system must be designed solely to offset envelope heat losses or gains.
2. The perimeter system must have at least one thermostatic control for each building orientation of 50 ft or more.
3. The perimeter system is controlled by at least one thermostat located in one of the zones served by the system.

The intent is that all major exposures are controlled by their own thermostat, and that the thermostat is located within the conditioned perimeter zone. Other temperature controls, such as outdoor temperature reset or solar compensated outdoor reset, do not meet these requirements of the Energy Code.

Example 4-23

Question

Can an energy management system be used to control the space temperatures?

Answer

Yes, provided the space temperature set points can be adjusted, either locally or remotely. This section sets requirements for "thermostatic controls" which need not be a single device like a thermostat; the control system can be a broader system like a DDC system. Some DDC systems employ a single cooling set point and a fixed or adjustable deadband. These systems comply if the deadband is adjustable or fixed at 5 degrees F or greater.

Thermostats with adjustable set points and deadband capability are not required for zones that must have constant temperatures to prevent the degradation of materials, an exempt process, or plants or animals (Exception 1 to §120.2(b)4). Included in this category are manufacturing facilities, hospital patient rooms, museums, and computer rooms. Chapter 13 describes mandated acceptance test requirements for thermostat control for packaged HVAC systems.

4.6.1.2 Hotel/Motel Guest Rooms Thermostats

§120.2(c)

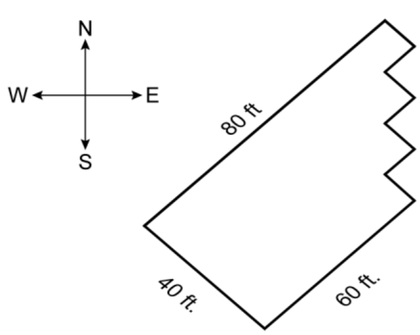
The Energy Code requires that thermostats in hotel/motel guest rooms have:

1. Numeric temperature set points in degrees F and degrees Celsius,
2. Set point stops that prevent the thermostat from being adjusted outside the normal comfort range (± 5-degree F or ± 3 degree Celsius). These stops must be concealed so that they are accessible only to authorized personnel.
3. Setback capabilities with a minimum of four separate set points per 24-hour period.

Example 4-24

Question

What is the perimeter zoning required for the building shown here?



Answer

The southeast and northwest exposures must each have at least one perimeter system control zone since they are more than 50 ft in length. The southwest exposure and the serrated east exposure do not face one direction for more than 50 continuous ft in length. They are therefore "minor" exposures and need not be served by separate perimeter system zones but may be served from either of the adjacent zones.

Example 4-25

Question

Pneumatic thermostats are proposed for zone control. However, the model specified cannot be adjusted to meet the range required by §120.2(a) to (c). How can this system comply?

Answer

§120.2(a) to (c) applies to "thermostatic controls" which can be a system of thermostats or control devices, not necessarily a single device. In this case, the requirement could be met by using multiple thermostats. The pneumatic thermostats could be used for zone control during occupied hours and need only have a range consistent with occupied temperatures (e.g., 68 degrees F to 78 degrees F), while two additional electric thermostats could be provided, one for setback control (adjustable down to 55 degrees F) and one for set-up (adjustable up to 85 degrees F). These auxiliary thermostats would be wired to temporarily override the system to maintain the setback/setup set points during off-hours.

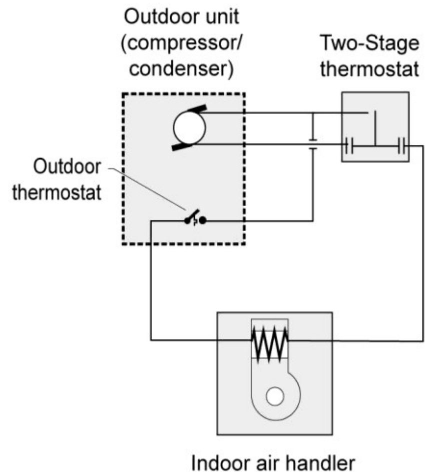
4.6.1.3 Heat-Pump Controls

§110.2(b) and §120.2(d)

Heat pumps with electric resistance supplemental heaters must have controls that limit the operation of the supplemental heater to defrost and as a second stage of heating when the heat pump alone cannot satisfy the load. The most effective solution is to specify an electronic thermostat designed specifically for use with heat pumps. This "anticipatory" thermostat can detect if the heat pump is raising the space temperature during warm-up fast enough to warrant locking out the auxiliary electric resistance heater.

This requirement can also be met using conventional electronic controls with a two-stage thermostat and an outdoor lockout thermostat wired in series with the auxiliary heater. The outdoor thermostat must be set to a temperature where the heat pump capacity is sufficient to warm up the space in a reasonable time (e.g., above 40 degrees F). This conventional control system is depicted schematically below in Figure 4-14.

Figure 4-15: Heat Pump Auxiliary Heat Control, Two-Stage and Outdoor Air Thermostats



4.6.1.4 Shut Off and Temperature Setup/Setback

§120.2(e)1,2 and 3, and §160.3(a)2D

For specific occupancies and conditions, each space-conditioning system must be provided with controls that comply with the following requirements:

A. The control can automatically shut off the equipment during unoccupied hours and shall have one of the following:

1. An automatic time switch device with the same characteristics that lighting devices must have, as described in Chapter 5, and a manual override accessible to the occupants that allows the system to operate up to four hours. The manual override can be included as a part of the control device, or as a separate override control.
2. An occupancy sensor. Since a building ventilation purge is required prior to normal occupancy, an occupancy sensor may be used to control the availability of heating and cooling but should not be used to control the outdoor ventilation system.
3. A four-hour timer that can be manually operated to start the system. As with occupancy sensors, the same restrictions apply to controlling outdoor air ventilation systems.

Exception to §120.2(e)1: The mechanical system serving retail stores and associated malls, restaurants, grocery stores, churches, or theaters equipped with seven-day programmable timers do not have to comply with the above requirements.

When shut down, the controls shall automatically restart the system to maintain:

B. A setback heating thermostat setpoint if the system provides mechanical heating. *Exception:* Thermostat setback controls are not required in nonresidential buildings in areas where the winter median of extremes outdoor air temperature is greater than 32 degrees F.

1. A setup cooling thermostat set point if the system provides mechanical cooling. *Exception:* Thermostat setup controls are not required in nonresidential buildings in areas where the summer design dry bulb 0.5 percent temperature is less than 100 degrees F.

C. Occupant-sensing zone controls

Space conditioning systems serving rooms that are required to have occupant sensing controls to satisfy the lighting control requirements of Section 130.1(c) and where Table 4-12 identifies the room or space is eligible to reduce the ventilation air to zero, shall incorporate this control strategy known as occupied standby mode. Occupancy sensors are required to report the room status as vacant if all sensors within that room do not detect activity for 20 minutes (building designers are allowed to set a shorter time threshold to define vacancy).

A space conditioning zone shall enter occupied standby mode when occupant sensing controls indicate that all the lighting zones within the zone are vacant for five minutes or less. After entering occupied standby mode, the cooling set point shall be increased by at least 2 degrees F and the heating set point shall be decreased by at least 2 degrees F, or for a multiple zone system with DDC to the zone level the cooling set point shall be increased by at least 0.5 degrees F and the heating set point shall be decreased by at least 0.5 degrees F. All airflow to the zone shall be shut off when in occupied standby mode. If the temperature in the zone drifts outside the deadband, then the full space conditioning system will turn on to satisfy the load in that zone.

This occupancy control must not prevent outside air ventilation of the space when the pre-occupancy ventilation purge cycle is required by §120.1(d)2. Pre-occupancy purge ventilates the space prior to scheduled occupancy each day to dilute and exhaust contaminants that have built up inside the building over night while the HVAC systems were off. Typically, the space is unoccupied during these periods and the occupancy control must not disable this scheduled ventilation cycle.

D. Exceptions for automatic shutoff, setback and setup, and occupant sensor setback:

1. *Exception to A, B, and C:* It can be demonstrated to the satisfaction of the enforcement agency that the system serves an area that must operate continuously.

2. *Exception to A, B, and C:* Systems have a full load demand of 2 kW or less, or 6,826 Btu/h, if they have a readily accessible manual shut off switch. Included is the energy consumed within all associated space-conditioning systems including compressors, as well as the energy consumed by any boilers or chillers that are part of the system.
3. *Exception to A and B:* Systems serve hotel/motel guest rooms, if they have a readily accessible manual shut-off switch.

E. Hotel/motel guest room controls:

§120.2(e)4

Hotel/motel guest rooms shall have captive card key controls, occupancy sensing controls, or automatic controls such that within 30 minutes of a guest leaving the room, set points are set-up of at least +5 degrees F (+3 degrees Celsius) in cooling mode and set-down of at least -5 degrees F (-3 degrees Celsius) in heating mode.

Example 4-26

Question

Can occupancy sensors be used in an office to shut off the VAV boxes during periods when the spaces are unoccupied?

Answer

Yes, only if the ventilation is provided through operable openings. With a mechanical ventilation design the occupancy sensor could be used to reduce the VAV box airflow to the minimum allowed for ventilation. It should not shut the airflow off completely; ventilation must be supplied to each space at all times when the space is usually occupied.

Example 4-27

Question

Must a 48,000 sq ft building with 35 fan coil units have 35-time switches?

Answer

No. More than one space-conditioning system may be grouped on a single time switch, subject to the area limitations required by the isolation requirements (see Isolation). In this case, the building would need two isolation zones, each no larger than 25,000 sq ft, and each having its own time switch.

Example 4-28

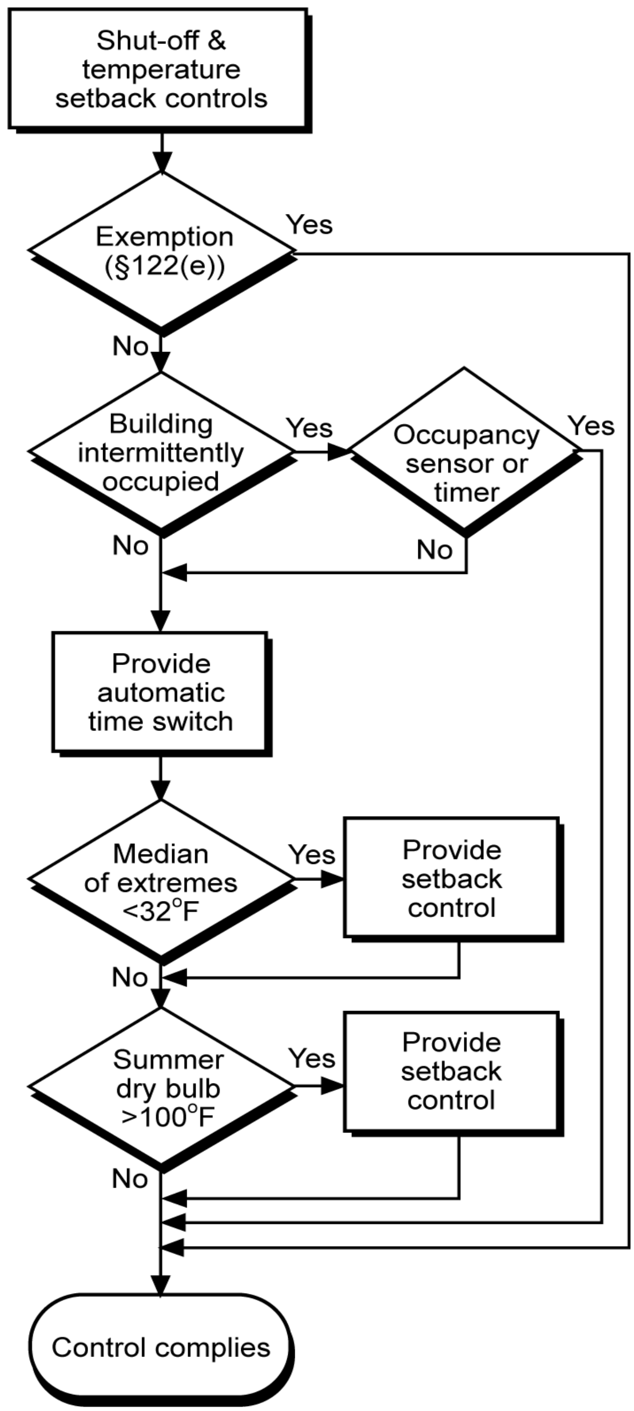
Question

Can a thermostat with set points determined by sensors (such as a bi-metal sensor encased in a bulb) be used to accomplish a night setback?

Answer

Yes. The thermostat must have two heating sensors, one each for the occupied and unoccupied temperatures. The controls must allow the setback sensor to override the system shutdown.

Figure 4-16: Shut-Off and Setback Controls Flowchart



These provisions are required by the Energy Code to reduce the likelihood that shut-off controls will be circumvented to cause equipment to operate continuously during unoccupied hours.

Example 4-29

Question

If a building has a system comprised of 30 fan coil units, each with a 300-watt fan, a 500,000 Btu/h boiler, and a 30-ton chiller, can an automatic time switch be used to control only the boiler and chiller (fan coils operate continuously)?

Answer

No. The 2 kW criterion applies to the system as a whole and is not applied to each component independently. While each fan coil only draws 300 W, they are served by a boiler and chiller that draw much more. The consumption for the system is well in excess of 2 kW.

Assuming the units serve a total area of less than 25,000 sq ft (see Isolation), one-time switch may control the entire system.

4.6.1.5 Infiltration Control

§120.2(f) and §160.3(a)2E

Outdoor air supply and exhaust equipment must incorporate dampers that automatically close when fans shut down.

Fans shut down when ventilation or conditioned air is not necessary for the building, which only occurs when a normally scheduled unoccupied period begins (such as overnight or a weekend for office buildings) or when occupancy sensors are used for ventilation control. The dampers may either be motorized, or of the gravity type. However only motorized dampers that remain closed when the fan turns on would be capable of accomplishing the best practice below.

Best Practice

Though the Energy Code only specify fan shut down, as a best practice outside air dampers should also remain completely closed during the unoccupied periods, even when the fan turns on to provide setback heating or cooling. However, to avoid instances of insufficient ventilation, or sick building syndrome, the designer should specify that the outside air dampers open and provide ventilation if:

- The unoccupied period is a one-hour pre-occupancy purge ventilation, as per §120.1(c)2.
- The damper is enabled by an occupant sensor in the building as per §120.1(c)5, indicating that there are occupants that demand ventilation air.
- The damper is enabled by an override signal as per §120.2(e)1, which includes an occupancy sensor but also an automatic time switch control device or manually operated four-hour timer.

Exception 1: Equipment that serves an area that must operate continuously.

Exception 2: Damper control required on gravity ventilators or other non-electrical equipment, provided that readily accessible manual controls are incorporated.

Exceptions 3 and 4: Damper control is not required at combustion air intakes and shaft vents, or where prohibited by other provisions of law. If the designer elects to install dampers or shaft vents to help control stack-induced infiltration, the damper should be motorized and controlled to open in a fire in accordance with applicable fire codes.

4.6.1.6 Isolation Area Controls

§120.2(g) and §160.3(a)2F

Large space-conditioning systems serving multiple zones may waste considerable quantities of energy by conditioning all zones when only a few are occupied. Typically, this occurs during evenings or weekends when less people are working. When the total area served by a system exceeds 25,000 sq ft, the Energy Code requires that the system be designed, installed, and controlled with area isolation devices to minimize energy consumption during these times. The requirements are:

1. The building shall be divided into isolation areas, the area of each not exceeding 25,000 sq ft. An isolation area may consist of one or more zones.
2. An isolation area cannot include spaces on different floors.
3. Each isolation area shall be provided with isolation devices such as valves or dampers that allow the supply of heating or cooling to be setback or shut off independently of other isolation areas.
4. Each isolation area shall be controlled with an automatic time switch, occupancy sensor, or manual timer. The requirements for these shut-off devices are the same as described previously in 4.5.1.4. As discussed previously for occupancy sensors, a building purge must be incorporated into the control sequences for normally occupied spaces, so occupancy sensors and manual timers are best limited to use in those areas that are intermittently occupied.

Any zones requiring continuous operation do not have to be included in an isolation area.

Example 4--30

Question

How many isolation zones does a 55,000 sq ft building require?

Answer

At least three. Each isolation zone may not exceed 25,000 sq ft.

A. Isolation of Zonal Systems

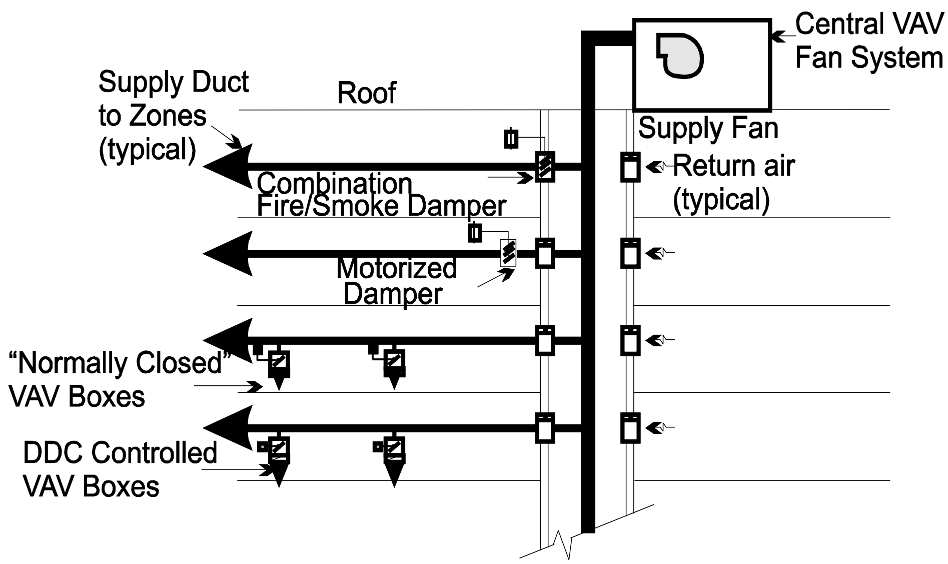
Small zonal type systems such as water loop heat pumps or fan coils may be grouped on automatic time-switch devices, with control interlocks that start the central plant equipment whenever any isolation area is occupied. The isolation requirements apply to equipment supplying heating and cooling only; central ventilation systems serving zonal type systems do not require these devices.

B. Isolation of Central Air Systems

Figure 4-17 below depicts four methods of area isolation with a central VAV system:

1. On the lowest floor, programmable DDC boxes can be switched on a separate time schedule for each zone or blocks of zones. When unoccupied, the boxes can be programmed to have zero minimum volume set points and unoccupied setback/setup set points. This form of isolation can be used for sections of a single floor distribution system.
2. On the second floor, normally closed pneumatic or electric VAV boxes are used to isolate zones or groups of zones. In this scheme the control source (pneumatic air or control power) for each group is switched on a separate control signal from an individual time schedule. Again, this form of isolation can be used for sections of a single floor distribution system.
3. On the third floor, isolation is achieved by inserting a single motorized damper on the trunk of the distribution ductwork. With the code requirement for fire/smoke dampers (see next numbered item) this method is somewhat obsolete. When applied, this method can only control a single trunk duct. Care must be taken to integrate the motorized damper controls into the fire/life safety system.
4. On the top floor, a combination fire smoke damper is controlled to provide the isolation. This control can only be used on a single trunk duct. Fire/smoke dampers required by code can be used for isolation at virtually no cost, provided that they are wired so that the fire life-safety controls take precedence over off-hour controls (local fire officials generally allow this dual usage of smoke dampers since it increases the likelihood that the dampers will be in good working order in the event of a fire). No isolation devices are required on the return.

Figure 4-17: Isolation Methods for a Central VAV System



Example 4-31

Question

Does each isolation area require a ventilation purge?

Answer

Yes. Consider each isolation area as if it were a separate air-handling system, each with its own time schedule, setback, and setup control.

C. Turndown of Central Equipment

Where isolation areas are provided, it is critical that the designer plans the central systems (fans, pumps, boilers, and chillers) to have sufficient stages of capacity or turndown controls to operate stably, as required to serve the smallest isolation area on the system. Failure to do so may cause fans to operate in surge, excessive equipment cycling and loss of temperature control. Schemes include:

1. Application of demand-based supply pressure reset for VAV fan systems. This will generally keep variable speed driven fans out of surge and can provide 10:1 turndown.
2. Use of pony chillers, an additional small chiller to be used at partial load conditions, or unevenly split capacities in chilled water plants. This may be required anyway to serve 24/7 loads.
3. Unevenly split boiler plants.

4.6.1.7 Automatic Demand Shed Controls

§110.12

HVAC systems with DDC to the zone level must be programmed to allow centralized demand shed for non-critical zones as follows:

1. The controls shall have the capability to remotely increase the operating cooling temperature set points by four degrees or more in all non-critical zones, via signal from a centralized contact or software point within an EMCS.
2. The controls shall have the capability to remotely decrease the operating heating temperature set points by four degrees or more in all non-critical zones, via signal from a centralized contact or software point within an EMCS.
3. The controls shall have the capability to remotely reset the temperatures in all non-critical zones to original operating levels, via signal from a centralized contact or software point within an EMCS.
4. The controls shall be programmed to provide an adjustable rate of change for the temperature increase, decrease, and reset.
5. The controls shall have the following features:
   a. The ability to be disabled by authorized facility operators.
   b. Controlled manually by authorized facility operators to allow adjustment of heating and cooling set points globally from a single point in the EMCS.
   c. Upon receipt of a demand response signal, the space-conditioning systems shall automatically conduct a centralized demand shed (as specified in one and two above) for non-critical zones during the demand response period.

The Energy Code defines a critical zone as a zone serving a process where reset of the zone temperature set point during a demand shed event might disrupt the process, including but not limited to data centers, telecom/private branch exchange rooms, and laboratories.

To comply with this requirement, each non-critical zone temperature-control loop will need a switch that adds in an offset on the cooling temperature set point from a central demand shed signal. A rate of change limiter can either be built into the zone control or into the functional block for the central offset value. The central demand shed signal can be activated either through a global software point or a hardwired digital contact.

This requirement is enhanced with an acceptance test to ensure that the system was programmed as required.

4.6.1.8 Economizer Fault Detection and Diagnostics

§120.2(i) and §160.3(a)2H

Economizer Fault Detection and Diagnostics (FDD) is a mandatory requirement for all newly installed air handlers with a mechanical cooling capacity greater than 33,000 Btu/hr and an air economizer.

The FDD system can be either a stand-alone unit or integrated. A stand-alone FDD unit is added onto the air handler, while an integrated FDD system is included in the air handler system controller or is part of the DDC system.

Where required, the FDD system shall meet each of the following requirements:

1. Temperature sensors shall be permanently installed to monitor system operation of outside air, supply air, and return air.
2. Temperature sensors shall have an accuracy of ±2 degrees F over the range of 40 degrees F to 80 degrees F.
3. The controller shall have the capability of displaying the value of each sensor.
4. The controller shall provide system status by indicating the following conditions:
    a. Free cooling available.
    b. Economizer enabled.
    c. Compressor enabled. For systems that don't have compressors, indicating "mechanical cooling enabled" also complies.
    d. Heating enabled if the system is capable of heating.
    e. Mixed air low limit cycle active.
5. The unit controller shall allow manual initiation of each operating mode so that the operation of cooling systems, economizers, fans, and heating system can be independently tested and verified.
6. Faults shall be reported using one of the following options:
    a. An EMCS that is regularly monitored by facility personnel
    b. Displayed locally on one or more zone thermostats or a device within five feet of a zone thermostat, clearly visible, at eye level and meet the following requirements:
        i. On the thermostat, device, or an adjacent written sign, there must be instructions displayed for how to contact the appropriate building personnel or an HVAC technician to service the fault.
        ii. In buildings with multiple tenants, the fault notification shall either be within property management offices or in a common space accessible by the property or building manager.
    c. Reported to a fault management application that automatically provides notification of the fault to a remote HVAC service provider. This allows the service provider to coordinate with an HVAC technician to service the fault.
7. The FDD system shall have the minimum capability of detecting the following faults:

a. Air temperature sensor failure/fault. This failure mode is a malfunctioning air temperature sensor, such as the outside air, discharge air, or return air. This could include loss of calibration, complete failure (either through damage to the sensor or its wiring) or failure due to disconnected wiring.

b. Not economizing when it should, meaning when programmed to do so. In this case, the economizer should be enabled yet is not providing free cooling. This leads to an unnecessary increase in mechanical cooling energy. For example, if the economizer high limit set point is too low (55˚F), or the economizer is stuck in the closed position.

c. Economizing when it should not, meaning when not programmed to do so. This is the opposite malfunction from the previous problem. In this case, conditions are such that the economizer should be at minimum ventilation position, but instead is open beyond the correct position. This leads to an unnecessary increase in heating and cooling energy. For example, if the economizer high limit set point is too high (82˚F), or the economizer is stuck in the open position.

d. Damper not modulating. This issue represents a stuck, disconnected, or otherwise inoperable damper that does not modulate open and closed. It is a combination of the previous two faults: not economizing when programmed to do so and economizing unnecessarily.

e. Excess outdoor air. This failure occurs when the economizer provides an excessive level of ventilation, usually much higher than is needed for design minimum ventilation. It causes an energy penalty during periods when the economizer should not be enabled (during cooling mode when outdoor conditions are higher than the economizer high limit set point). During heating mode, excess outdoor air will increase heating energy.

8. The FDD system shall be certified to the Energy Commission, by the manufacturer of the FDD system, to meet the requirements one through seven, above. The manufacturer submittal package is available in Joint Appendices *JA6.3 Economizer Fault Detection and Diagnostics Certification Submittal Requirements*.

   For air handlers controlled by DDC (including packaged systems), FDD sequences of operations must be developed to adhere with the requirements of §120.2(i)1 through 7. FDD systems controlled by DDC are not required to be certified to the Energy Commission, but manufacturers, controls suppliers, or other market actors can choose to apply for certification. For DDC based FDD systems, a new acceptance test has been developed to test the sequences of operations in the field to verify that they in-fact comply with the required faults of §120.1(i).

   Although not required by the Energy Code, ASHRAE Guideline 36-2017 is a good reference for developing sequences of operations specifically for the faults listed in 120.2(i). The purpose of Guideline 36 is to provide uniform sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems that are intended to maximize HVAC system energy efficiency and performance, provide control stability, and allow for real-time fault detection and diagnostics. To properly adhere to Guideline 36, all sequences of operations design elements in Sections 5.16.14 and/or 5.18.13 of that guideline must be implemented, including defining operating states, the use of an alarm delay, and the installation of an averaging mixed air temperature sensor. If a designer uses Guideline 36 to detect the required economizer faults in Title 24 Section 120.2(i), the sequences of operations should include Guideline 36 Fault Conditions numbers #2, 3, and 5 through 13, at a minimum. Other Title 24 FDD requirements in Section 120.2(i) and acceptance tests are not met by including these fault conditions into sequences of operations and must be met through other means.

4.6.1.9 Direct Digital Controls

§120.2(j) and § 160.3(a)2l

The requirement for DDC will mostly impact smaller buildings, since it is already common practice to install DDC in medium and large buildings; primarily due to the size and complexity of HVAC systems of medium and large buildings, which DDC is well suited to operate. Small buildings in the past did not require DDC and therefore could not take advantage of basic energy savings strategies.

DDC systems facilitate energy saving measures through monitoring and regulating the HVAC systems and optimizing their efficient operation. With most buildings requiring DDC, the following energy saving measures will be triggered if DDC is to the zone level:

1. DCV (mandatory) - Section 4.3.9
2. Automatic Demand Shed Controls (mandatory) - Section 4.6.1.7
3. Optimum Start/Stop Controls (mandatory) - Section 4.6.1.10
4. Set point Reset Controls for VAV systems (prescriptive) - Section 4.6.2.3

For further explanation, see the appropriate compliance manual sections for the measures listed above.

The Energy Code mandate DDC for only certain building applications with minimum qualifications or equipment capacities, as specified in Table 120.2-A of the Energy Code, see Table 4-5 below for a duplicate of this table.

Table 4-5: DDC Applications and Qualifications

BUILDING STATUS	APPLICATIONS	QUALIFICATIONS
Newly Constructed Buildings	Air handling system and all zones served by the system	Individual systems supplying more than three zones and with design heating or cooling capacity of 300 kBtu/h and larger
Newly Constructed Buildings	Chilled water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300 kBtu/h (87.9 kW) and larger
Newly Constructed Buildings	Hot water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300 kBtu/h (87.9 kW) and larger
Additions or Alterations	Zone terminal unit such as VAV box	Where existing zones served by the same air handling, chilled water, or hot water systems that have DDC
Additions or Alterations	Air handling system or fan coil	Where existing air handling system(s) and fan coil(s) served by the same chilled or hot water plant have DDC
Additions or Alterations	New air handling system and all new zones served by the system	Individual systems with design heating or cooling capacity of 300 kBtu/h and larger and supplying more than three zones and more than 75 percent of zones are new
Additions or Alterations	New or upgraded chilled water plant	Where all chillers are new and plant design cooling capacity is 300 kBtu/h (87.9 kW) and larger
Additions or Alterations	New or upgraded hot water plant	Where all boilers are new and plant design heating capacity is 300 kBtu/h (87.9 kW) and larger

Source: California Energy Commission, Building Energy Efficiency Standards, Table 120.2-A

Buildings that do not meet the specified minimum qualifications are not required to install DDC.

Follow the flowchart in Figure 4-18**Error! Reference source not found.** to determine if a DDC system is required for newly constructed buildings, additions, or alterations. The Building Status Flowchart will indicate which equipment flowchart (

Figure **4-19** throughFigure 4-23) should be used for each type of HVAC equipment that will be installed in the building.

The flowcharts will indicate whether DDC is required for the building, how it should be applied to the equipment and whether it is required to be installed to the zone level.

Figure 4-18: Building Status Flowchart

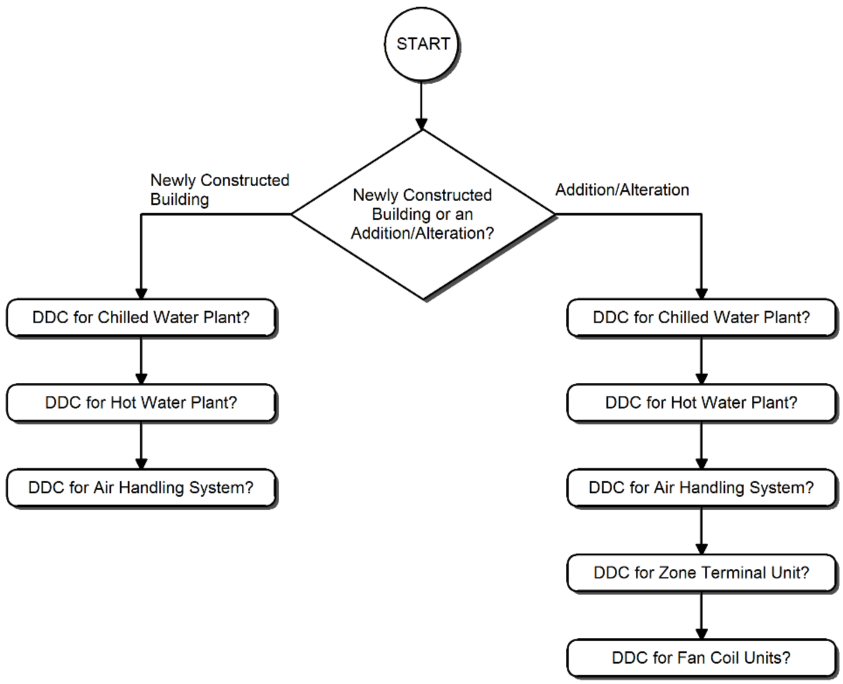


Figure 4-19: Chilled Water Plant Flowchart

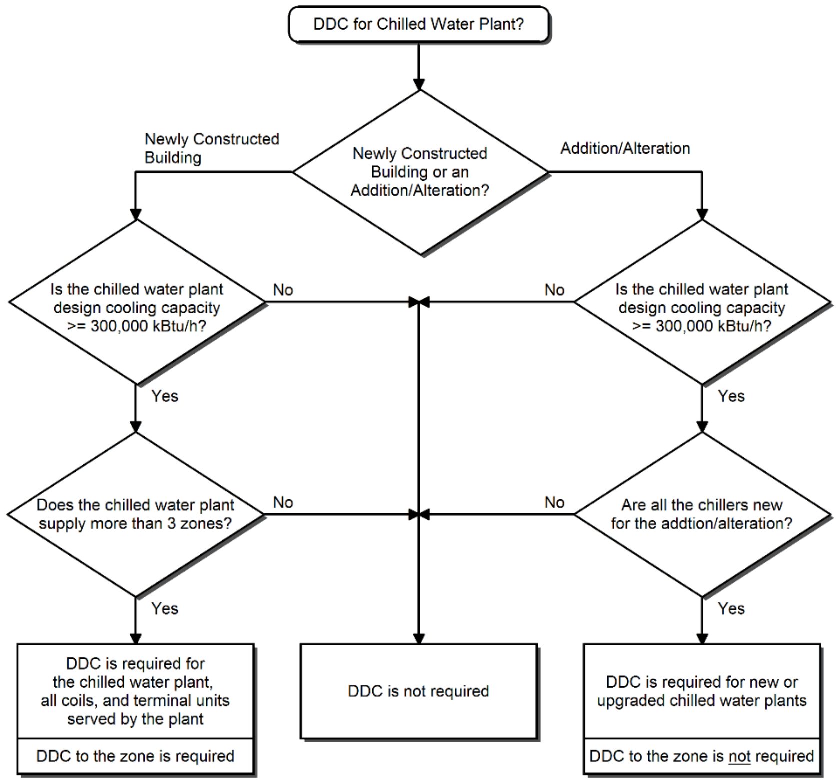


Figure 4-20: Hot Water Plant Flowchart

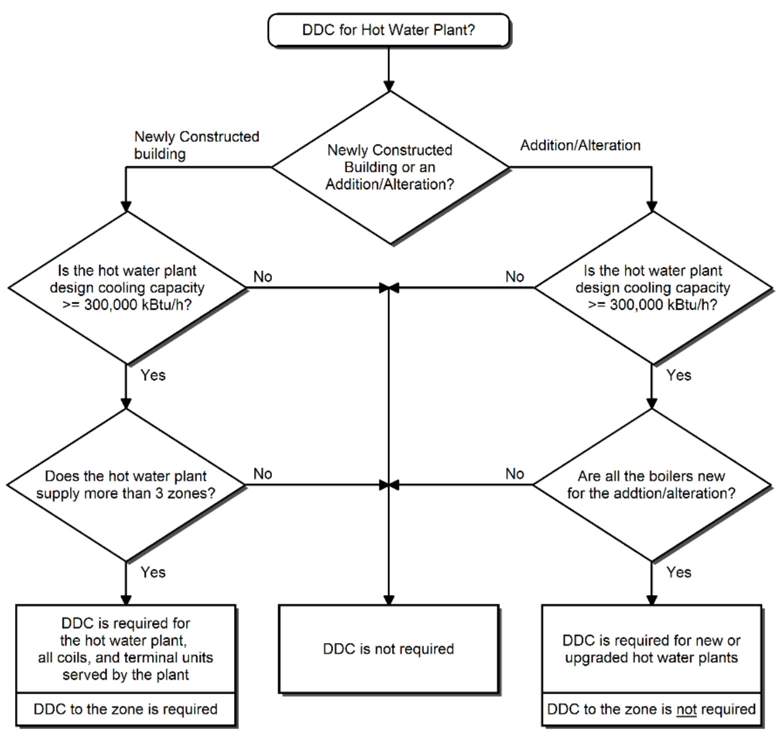


Figure 4-21: Air Handling System Flowchart

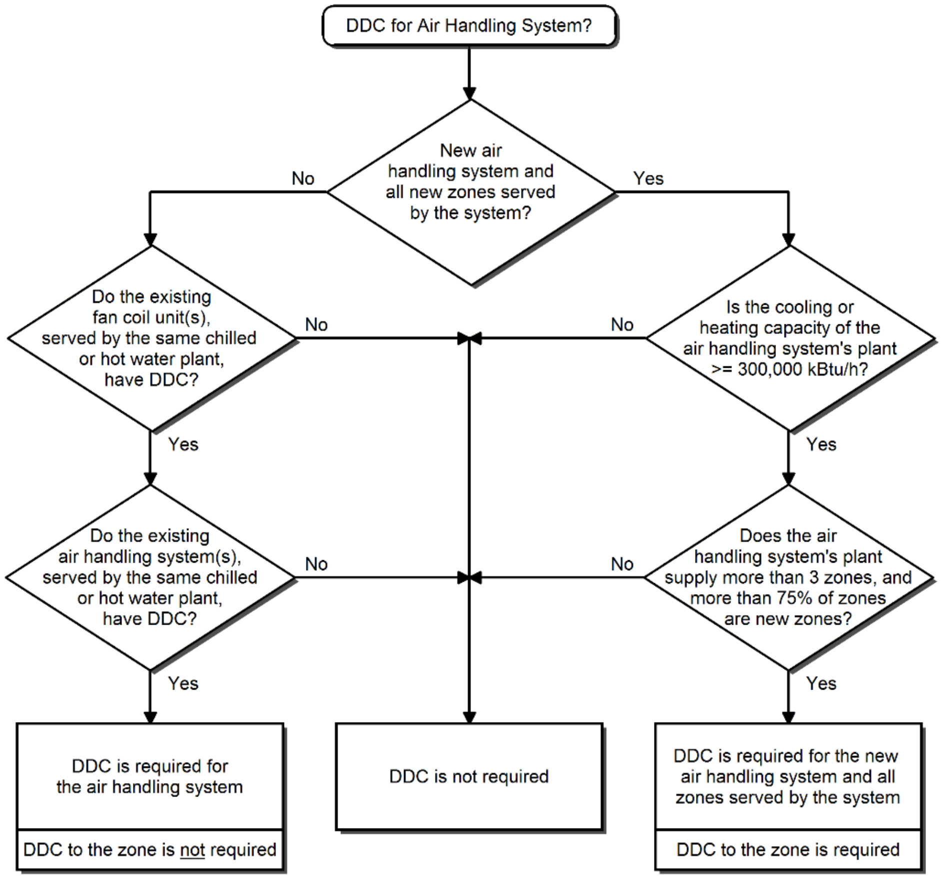


Figure 4-22: Zone Terminal Unit Flowchart

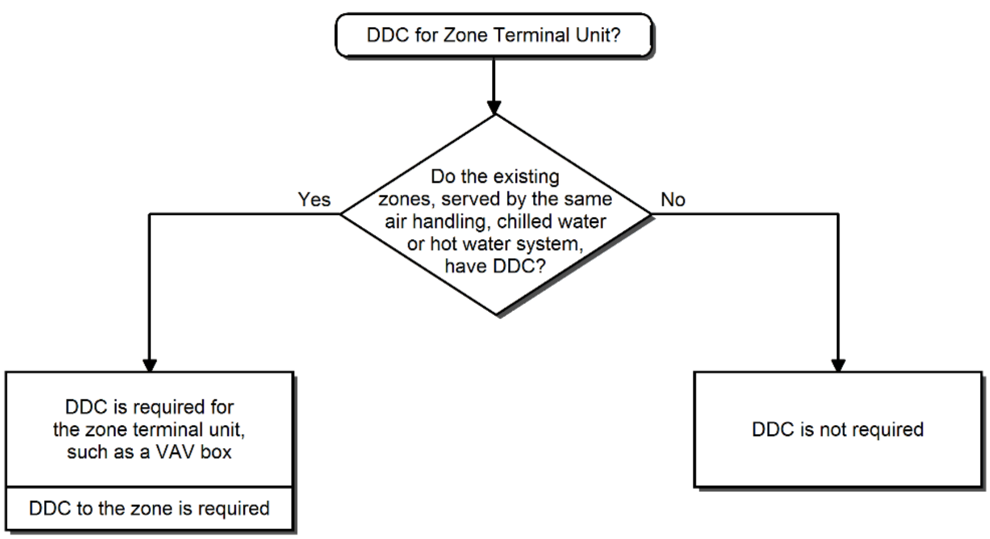
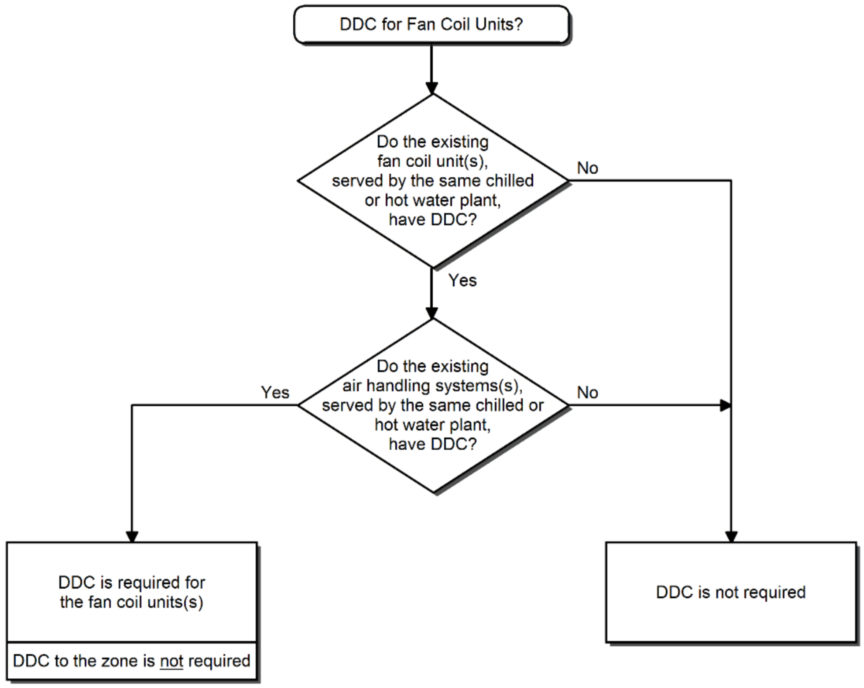


Figure 4-23: Fan Coil Units Flowchart



For additions or alterations to buildings, zones that are not part of the addition or alteration are not required to be retrofitted with DDC to the zone. Pre-existing DDC systems in buildings are not required to be retrofitted so DDC is to the zone.

Example 4-32

Question

If a newly constructed building has a HVAC system comprised of an air handling system, serving four zones and a chilled water plant with a design cooling capacity of 250,000 Btu/h, is DDC required?

Answer

No. Although the HVAC system is serving more than three zones, the chilled water plant does not meet the minimum design cooling capacity of 300,000 Btu/h (300 kBtu/h). A DDC system would be required if the design cooling capacity was 300,000 Btu/h or larger.

Example 4-33

Question

If an addition to a building requires a new VAV box, is DDC required?

Answer

Maybe. The answer is dependent upon whether there is already a DDC system for the zones served by the same air handling, chilled water, or hot water system. Essentially this is to ensure that if a DDC system is already installed, then it must be continued throughout the building, including the addition.

Example 4-34

Question

If a building's chilled water plant is upgraded with new chillers that have a design capacity of 500 kBtu/h and serves three zones, is DDC required?

Answer

Yes. The criterion that triggers the DDC requirement is that the plant upgrade is installing **new** chillers with a cooling capacity greater than 300 kBtu/h. In this case, the number of zones is irrelevant for determining if DDC is required.

The Energy Code now require the mandated DDC system to have the following capabilities to ensure that the full energy saving benefits of DDC:

1. Monitor zone and system demand for fan pressure, pump pressure, heating, and cooling
2. Transfer zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers
3. Automatically detect those zones and systems that may be excessively driving the reset logic and generate an alarm, or other indication, to the system operator
4. Readily allow operator removal of zone(s) from the reset algorithm
5. Trend and graphically display input and output points for new buildings
6. Reset set points in non-critical zones, signal from a centralized contact or software point, as described in 4.5.1.7.

4.6.1.10 Optimum Start/Stop Controls

§120.2(k) and §160.3(a)2l

Optimum start/stop controls are an energy saving technique where the HVAC system determines the optimum time to turn on or turn off the HVAC system. This ensures that the space reaches the appropriate temperature during occupied hours only, without wasting energy to condition the space during unoccupied hours. It applies to heating and cooling.

Optimum start controls are designed to automatically adjust the start time of a space conditioning system each day. The purpose of these controls is to bring the space temperature to the desired occupied temperature levels at the beginning of scheduled occupancy. The controls take in to account the space temperature, outside ambient temperature, occupied temperature, amount of time prior to scheduled occupancy, and if present, the floor temperatures of mass radiant floor slab systems.

Optimum stop controls are designed to automatically adjust the stop time of a space conditioning system each day with the intent of letting the space temperature coast to the unoccupied temperature levels after the end of scheduled occupancy. The controls shall take in to account the space temperature, outside ambient temperature, unoccupied temperature, and the amount of time prior to scheduled occupancy.

Systems that must operate continuously are exempt.

4.6.2 Prescriptive Requirements

4.6.2.1 Space Conditioning Zone Controls

§140.4(d) and §170.2(c)4B

Each space-conditioning zone shall have controls that prevent:

- Reheating of air that has been previously cooled by mechanical cooling equipment or an economizer.
- Recooling of air that has been previously heated. This does not apply to air returned from heated spaces.
- Simultaneous heating and cooling in the same zone, such as mixing supply air that has been previously mechanically heated with air that has been previously cooled, either by mechanical cooling or by economizer systems.

Zones served by VAV systems that are designed and controlled to reduce the volume of reheated, recooled, or mixed air to a minimum. The controls must meet all of the following:

a. For each zone with DDC:

1. The volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of 50 percent of the peak primary airflow or the design zone outdoor airflow rate, per Section 4.3.
2. The volume of primary air in the dead band shall not exceed the design zone outdoor airflow rate, per Section 4.3.

ii. The first stage of heating consists of modulating the zone supply air temperature set point up to a maximum set point no higher than 95 degrees F while the airflow is maintained at the deadband flow rate.

iii. The second stage of heating consists of modulating the airflow rate from the deadband flow rate up to the heating maximum flow rate.

iv. For each zone without DDC, the volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of 30 percent of the peak primary airflow or the design zone outdoor airflow rate, per Section 4.3.

For systems with DDC to the zone level, the controls must be able to support two different maximums -- one each for heating and cooling. This control is depicted in Figure 4-24 below. In cooling, this control scheme is similar to a traditional VAV reheat box control. The difference is what occurs in the deadband between heating and cooling and in the heating mode. With traditional VAV control logic, the minimum airflow rate is typically set to the largest rate allowed by code. This airflow rate is supplied to the space in the deadband and heating modes. With the "dual maximum" logic, the minimum rate is the lowest allowed by code (e.g., the minimum ventilation rate) or the minimum rate the controls system can be set to (which is a function of the VAV box velocity pressure sensor amplification factor and the accuracy of the controller to convert the velocity pressure into a digital signal). As the heating demand increases, the dual maximum control first resets the discharge air temperature (typically from the design cold deck temperature up to 85 or 90 degrees F) as a first stage of heating then, if more heat is required, it increases airflow rate up to a "heating" maximum airflow set point, which is the same value as what traditional control logic uses as the minimum airflow set point. Using this control can save significant fan, reheat and cooling energy while maintaining better ventilation effectiveness as the discharge heating air is controlled to a temperature that will minimize stratification.

This control requires a discharge air sensor and may require a programmable VAV box controller. The discharge air sensor is very useful for diagnosing control and heating system problems even if they are not actively used for control.

Figure 4-24: Dual-Maximum VAV Box Control Diagram with Minimum Flow in Deadband

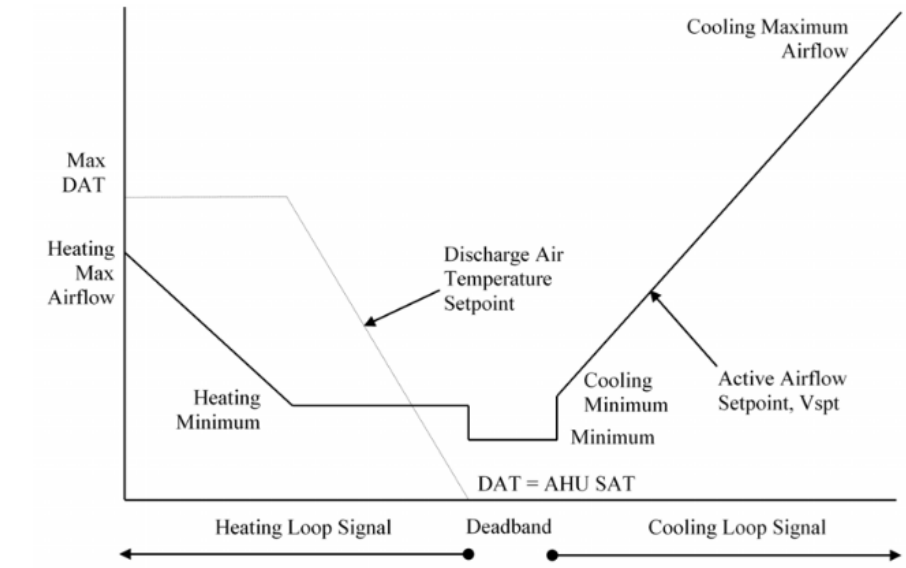
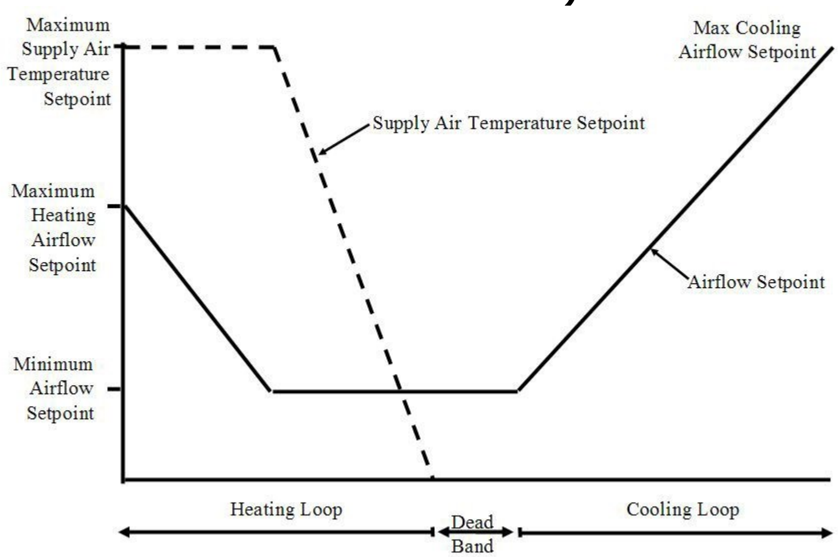


Figure 4-23b: Dual-Maximum VAV Box Control Diagram (for systems without DDC)



For systems without DDC to the zone (such as electric or pneumatic thermostats), the airflow that is reheated is limited to a maximum of either 30 percent of the peak primary airflow or the minimum airflow required to ventilate the space, whichever is greater.

Certain exceptions exist for space conditioned zones with one of the following:

1. Special pressurization relationships or cross contamination control needs (laboratories are an example of spaces that might fall in this category)

2. Site-recovered or site-solar energy providing at least 75 percent of the energy for reheating, or providing warm air in mixing systems
3. Specific humidity requirements to satisfy exempt process needs (computer rooms are explicitly not covered by this exception)
4. Zones with a peak supply air quantity of 300 cfm or less
5. Systems with healthcare facilities

Example 4--35

Question

What are the limitations on VAV box minimum airflow set point for a 1,000 sq ft office having a design supply of 1,100 cfm and eight people?

Answer

For a zone with pneumatic thermostats, the minimum cfm cannot exceed the larger of:

a. 1,100 cfm x 30 percent = 330 cfm; or

b. the minimum ventilation rate: which is the larger of

1) 1,000 ft^2 x 0.15 cfm/ft^2 = 150 cfm; and

2) 8 people x 15 cfm/person = 120 cfm

Thus, the minimum airflow set point can be no larger than 330 cfm.

For a zone with DDC to the zone, the minimum cfm in the deadband cannot exceed the minimum ventilation rate. which is the larger of

1) 1,000 ft^2 x 0.15 cfm/ft^2 = 150 cfm; and

2) 8 people x 15 cfm/person = 120 cfm

Thus, the minimum airflow set point in the dead band can be no larger than 150 cfm. And this can rise to 1100 cfm X 50 percent or 550 cfm at peak heating.

For either control system, based on ventilation requirements, the lowest minimum airflow set point must be at least 150 cfm, or transfer air must be provided in this amount.

4.6.2.2 Economizers

§140.4(e) and § 170.2(c)4C

Airside economizers are required on air handler systems with a mechanical cooling capacity greater than 33,000 Btu/h (2.75 tons) and must be fully integrated (capable of modulating outside air and return air dampers to supply all of the design supply air as outside air). Under certain conditions an applicable economizer exception can be taken.

Waterside economizers are required for chilled-water systems without a fan or that induce airflow (such as chilled beams) based on the total chilled water system capacity and climate zone as described under Table 4-17. Additionally, waterside economizers must be capable of providing 100 percent of the expected system cooling load at an outside air temperature of 50 degrees F dry-bulb and 45 degrees F wet-bulb and below.

Table 4-6 - Chilled Water System Cooling Capacity

Climate Zones	Total Building Chilled Water System Capacity, Minus Capacity of Cooling units with Air Economizers Building Water-Cooled Chilled-Water Systems	Total Building Chilled Water System Capacity, Minus Capacity of Cooling units with Air Economizers Air-Cooled Chilled-Water Systems or District Chilled-Water Systems
15	≥ 960,000 Btu/h (280 kW)	≥ 1,250,000 Btu/h (365 kW)
1,2,3,4,5,6,7,8,9 10,11,12,13,14	≥ 720,000 Btu/h (210 kW)	≥ 940,000 Btu/h (275 kW)
16	≥ 1,320,000 Btu/h (385 kW)	≥ 1,720,000 Btu/h (505 kW)

Source: California Energy Commission, Building Energy Efficiency Standards, Table 140.4-E

Depicted below in

Figure **4-27**is a schematic of an air-side economizer. All air-side economizers have modulating dampers on the return and outdoor air streams.

Best Practice:

To provide 100 percent of the design supply air, designers will need to specify an economizer with a nominal capacity sufficient to deliver the design air flow rate when the supply air damper is in the fully open position, and the return air damper is completely closed.

An appropriately sized economizer can also be estimated by determining the face velocity passing through the economizer, using the design airflow and the area of the economizer damper/duct opening.

The design airflow (cfm) should be available from the mechanical drawings or air handler cutsheet. The minimum area (sq ft) through which air is flowing from the outside to the fan can be measured in the field, or it can be found on the economizer damper cutsheet if the economizer damper is the smallest area. Dividing the design airflow by the smallest area will give the velocity of the air in ft per min.

Appropriately sized economizers that can supply 100 %percent of the supply airflow without large pressure drops typically have face velocities of less than 2,000 ft per min.

To maintain acceptable building pressure, systems with an airside economizer must have provisions to relieve or exhaust air from the building. In Figure 4-25, three common forms of building pressure control are depicted:

- Option 1: barometric relief
- Option 2: a relief fan generally controlled by building static pressure
- Option 3: a return fan often controlled by tracking the supply

Figure 4-26depicts an integrated air-side economizer control sequence. On first call for cooling the outdoor air damper is modulated from minimum position to 100 percent outdoor air. As more cooling is required, the damper remains at 100 percent outdoor air as the cooling coil is sequenced on.

Graphics of water-side economizers are presented in Section 4.10.7.2 at the end of this chapter.

Figure 4-25: Air-Side Economizer Schematic

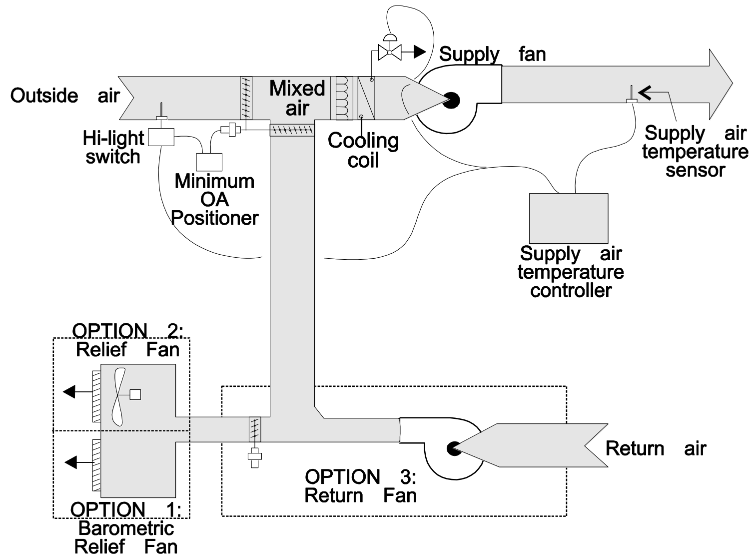
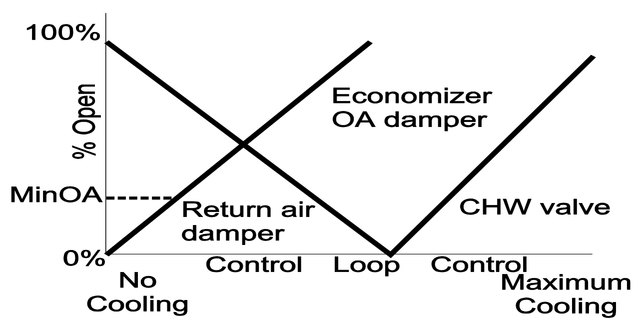


Figure 4-26: Typical Air-Side Economizer Control Sequencing



A. Economizers are not required where:

Exceptions to §140.4(e)1 and §170.2(c)4Ci

16. Outside air filtration and treatment for the reduction of unusual outdoor contaminants make compliance unfeasible.

17. Increased overall building TDV energy use results. This may occur where economizers adversely impact other systems, such as humidification, dehumidification, or supermarket refrigeration systems.

18. Systems serving hotel/motel guest rooms.

19. Cooling systems have the cooling efficiency that meets or exceeds the cooling efficiency improvement requirements in Table 4-18 (typically used for VRF systems).

20. Fan systems primarily serving computer room(s). See §140.9 (a) for computer room economizer requirements.

21. Systems utilizing dedicated outside air systems (DOAS) for ventilation capable of providing at least 0.3 cfm/sf and exhaust air heat recovery can take an economizer exception for their independent space-cooling air handlers (typically VRF or WSHP), if those systems are less than 54,000 Btu/h (4.5 tons).

22. Where the use of an air economizer in controlled environment horticulture spaces will affect carbon dioxide enrichment systems.

B. If an economizer is required, it must be:

§140.4(e)2 and §170.2(c)4Cii

1. Designed and equipped with controls that do not increase the building heating energy use during normal operation. This prohibits the application of single-fan dual-duct systems and traditional multizone systems using the Prescriptive Approach of compliance. With these systems, the operation of the economizer to pre-cool the air entering the cold deck also precools the air entering the hot deck and thereby increases the heating energy.

   Exception: when at least 75 percent of the annual heating is provided by site-recovered or site-solar energy.

2. Fully integrated into the cooling system controls so that the economizer can provide partial cooling even when mechanical cooling is required to meet the remainder of the cooling load. On packaged units with stand-alone economizers, a two-stage thermostat is necessary to meet this requirement.

The requirement that economizers be designed for concurrent operation is not met by some popular water economizer systems, such as those that use the chilled water system to convey evaporatively-cooled condenser water for “free” cooling. Such systems can provide all of the cooling load, but when the point is reached where condenser water temperatures cannot be sufficiently cooled by evaporation; the system controls throw the entire load to the mechanical chillers. Because this design cannot allow simultaneous economizer and refrigeration system operation, it does not meet the requirements of this section. An integrated water-side economizer which uses condenser water to precool the Chilled Water Return (CHWR) before it reaches the chillers (typically using a plate-and-frame heat exchanger) can meet this integrated operation requirement.

Table 4-18: Economizer Trade-Off Table for Cooling Systems

Climate Zone	Efficiency Improvement [a]
1	70%
2	65%
3	65%
4	65%
5	70%
6	30%
7	30%
8	30%
9	30%
10	30%
11	30%
12	30%
13	30%
14	30%
15	30%
16	70%

Source: California Energy Commission, Building Energy Efficiency Standards ,Table 140.4-A

[a] If a unit is rated with an IPLV, IEER or SEER, then to eliminate the required air or water economizer, the applicable minimum cooling efficiency of the HVAC unit must be increased by the percentage shown. If the HVAC unit is only rated with a full load metric, such as EER or COP cooling, then that metric must be increased by the percentage shown.

C. Air-side economizer high limit switches

§140.4(e)2C and §170.2(c)4Ciic

If an economizer is required by §140.4(e)1, and an air economizer is used to meet the requirement, the air side economizer is required to have high-limit shut-off controls that comply with Table 4-19.

1. The first column identifies the high limit control category. There are three categories allowed in this prescriptive requirement: fixed dry bulb; differential dry bulb; and fixed enthalpy plus fixed dry bulb.
2. The second column represents the California climate zone. “All” indicates that this control type complies in every California climate.
3. The third and fourth columns present the high-limit control set points required.

The Energy Code eliminated the use of fixed enthalpy, differential enthalpy, and electronic enthalpy controls. Research on the accuracy and stability of enthalpy controls led to their elimination (with the exception of use when combined with a fixed dry-bulb sensor). The enthalpy-based controls can be employed if the project uses the performance approach. However, the performance model will show a penalty due to the inaccuracy of the enthalpy sensors.

Table 4-8: Air Economizer High Limit Shut-Off Control Requirements

Device Type[a]	**Climate Zones**	**Required High Limit (Economizer Off When): Equation[b]**	**Required High Limit (Economizer Off When): Description**
Fixed Dry Bulb	1, 3, 5, 11-16	T_{OA} > 75° F	Outdoor air temperature exceeds 75° F
Fixed Dry Bulb	2, 4, 10	T_{OA} > 73° F	Outdoor air temperature exceeds 73° F
Fixed Dry Bulb	6, 8, 9	T_{OA} > 71° F	Outdoor air temperature exceeds 71° F
Fixed Dry Bulb	7	T_{OA} > 69° F	Outdoor air temperature exceeds 69° F
Differential Dry Bulb	1, 3, 5, 11-16	T_{OA} > T_{RA}° F	Outdoor air temperature exceeds return air temperature
Differential Dry Bulb	2, 4, 10	T_{OA} > T_{RA}-2° F	Outdoor air temperature exceeds return air temperature minus 2° F
Differential Dry Bulb	6, 8, 9	T_{OA} > T_{RA}-4° F	Outdoor air temperature exceeds return air temperature minus 4° F
Differential Dry Bulb	7	T_{OA} > T_{RA}-6° F	Outdoor air temperature exceeds return air temperature minus 6° F
Fixed Enthalpy[c] + Fixed Dry Bulb	All	h_{OA} > 28 Btu/lb[c] or T_{OA} > 75° F	Outdoor air enthalpy exceeds 28 Btu/lb of dry air[c] or Outdoor air temperature exceeds 75° F

[a] Only the high limit control devices listed are allowed to be used and at the set points listed. Others such as dew point, fixed enthalpy, electronic enthalpy, and differential enthalpy controls, may not be used in any climate zone for compliance with §140.4(e)1, unless approval for use is provided by the Energy Commission executive director

[b] Devices with selectable (rather than adjustable) set points shall be capable of being set to within two degrees F and two Btu/lb of the set point listed.

[c] At altitudes substantially different than sea level, the fixed enthalpy limit value shall be set to the enthalpy value at 75 degrees F and 50 percent relative humidity. As an example, at approximately 6,000-foot elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

Source: California Energy Commission, Building Energy Efficiency Standards, Table 140.4-B

D. Air Economizer Construction

§140.4(e)2D and §170.2(c)4Ciii

If an economizer is required by §140.4(e)1, and an air economizer is used to meet the requirement, then the air economizer, and all air dampers shall have the following features:

1. A five-year factory warranty for the economizer assembly.
2. Certification by the manufacturer that equipment has been tested and is able to open and close against the rated airflow and pressure of the system for at least 60,000 damper opening and closing cycles. Required equipment includes, but is not limited to, outdoor air dampers, return air dampers, drive linkages and actuators.
3. Economizer outside air and return air dampers shall have a maximum leakage rate of 10 cfm/sq ft at 250 Pascals (1.0 in. w.g) when tested in accordance with AMCA Standard 500-D. The leakage rates for the outside and return dampers shall be certified to the Energy Commission in accordance with §110.0.
4. If the high-limit control uses either a fixed dry-bulb, or fixed enthalpy plus fixed dry-bulb control, the control shall have an adjustable set point.
5. Economizer sensors shall be calibrated within the following accuracies:
    a. Dry bulb (db) and wet bulb (wb) temperatures accurate to plus or minus 2 degrees F over the range of 40 degrees F to 80 degrees F.
    b. Enthalpy accurate to plus or minus 3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
    c. Relative humidity (RH) accurate to plus or minus 5 percent over the range of 20 percent to 80 percent
6. Data of sensors used for control of the economizer shall be plotted on a sensor performance curve.
7. Sensors used for the high limit control shall be located to prevent false readings, including but not limited to, being properly shielded from direct sunlight.
8. Relief air systems shall be capable of providing 100 percent outside air without over-pressurizing the building.

E. Compressor unloading

§140.4(e)2E and §170.2(c)4Civ

Systems that include an air economizer must comply with the following requirements:

1. Unit controls shall have mechanical capacity controls interlocked with economizer controls such that the economizer is at 100 percent open position

when mechanical cooling is on and does not begin to close until the leaving air temperature is less than 45 degrees F.

2. Direct Expansion (DX) units greater than 65,000 Btu/hr that control the capacity of the mechanical cooling directly based on occupied space temperature shall have a minimum of two stages of mechanical cooling capacity.
3. DX units not within the scope of number two (above), shall comply with the requirements in **Table 4-20**, and have controls that do not false load the mechanical cooling system by limiting or disabling the economizer or by any other means, except at the lowest stage of mechanical cooling capacity.

Table 4-20: Direct Expansion Unit Requirements for Cooling Stages and Compressor Displacement

Cooling Capacity	Minimum Number of Mechanical Cooling Stages	Minimum Compressor Displacement
≥65,000 Btu/h and < 240,000 Btu/h	3 stages	≤ 35% full load
≥ 240,000 Btu/h	4 stages	≤ 25% full load

Source: California Energy Commission, Building Energy Efficiency Standards, Table 140.4-C

Chapter 14 of this manual describes mandated acceptance test requirements for economizers.

If the economizer is factory-calibrated the economizer acceptance test is not required at installation. A calibration certificate of economizer control sensors (outdoor air temperature, return air temperature, etc.) must be submitted to the local code enforcement agency in the permit application.

F. Water Economizer Specific Requirements

§140.4(e)3 and §170.2(c)4Cv

Unlike air-side economizers, water economizers have parasitic energy losses that reduce the cooling energy savings. One of these losses comes from increases in pumping energy. To limit the losses, the Energy Code requires that precooling coils and water-to-water heat exchangers used as part of a water economizer system have either 1) a water-side pressure drop of less than 15 feet of water, or 2) a secondary loop so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (non-economizer) mode.

Water economizer systems must also be integrated with the mechanical cooling system so that they are capable of providing partial cooling--even when additional mechanical cooling is required to meet the remainder of the cooling load. This includes controls that do not false load the mechanical cooling system by limiting or disabling the economizer, or by any other means--such as hot gas bypass--except at the lowest stage of mechanical cooling.

Figure 4-27: Economizer Flowchart

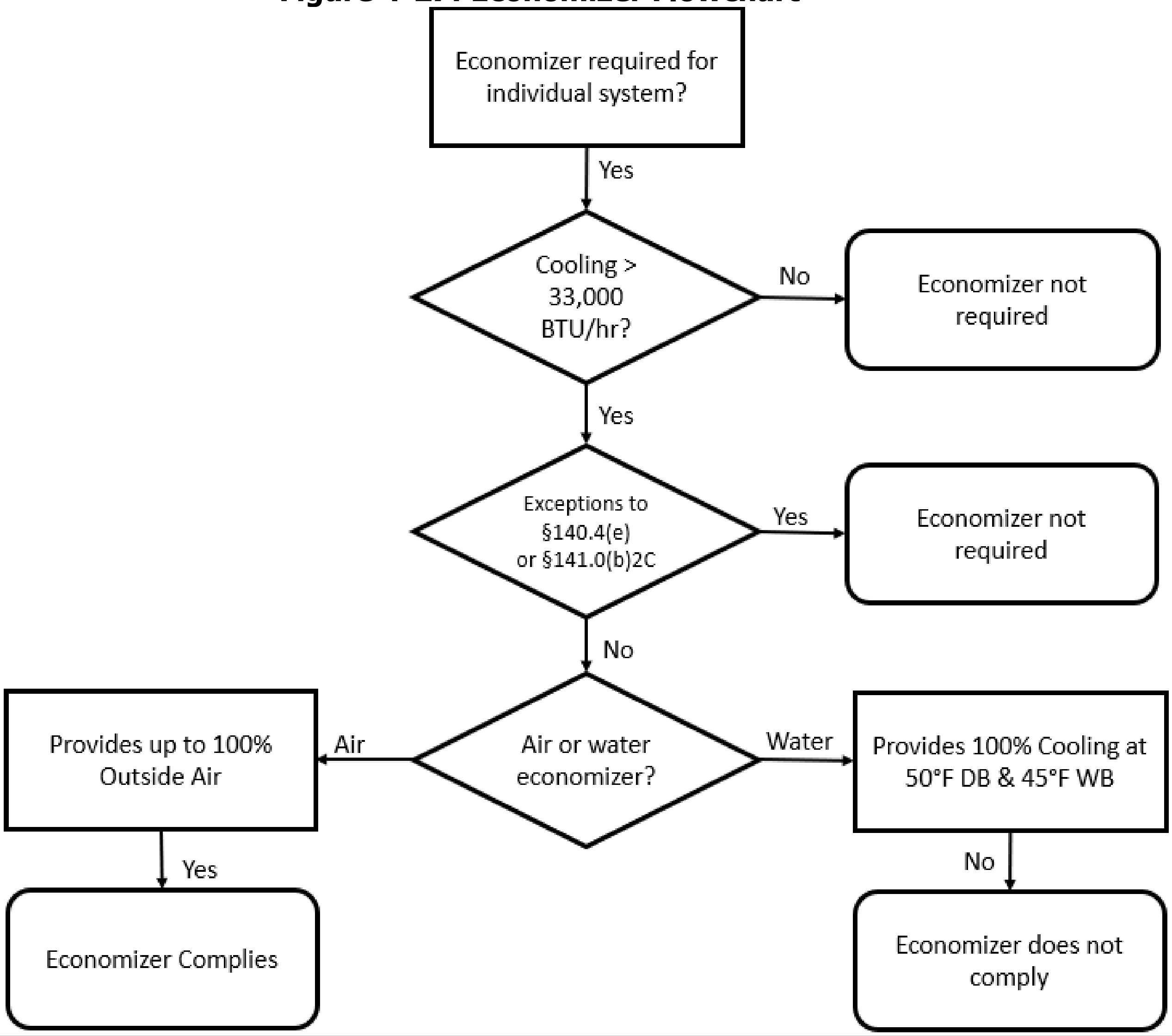
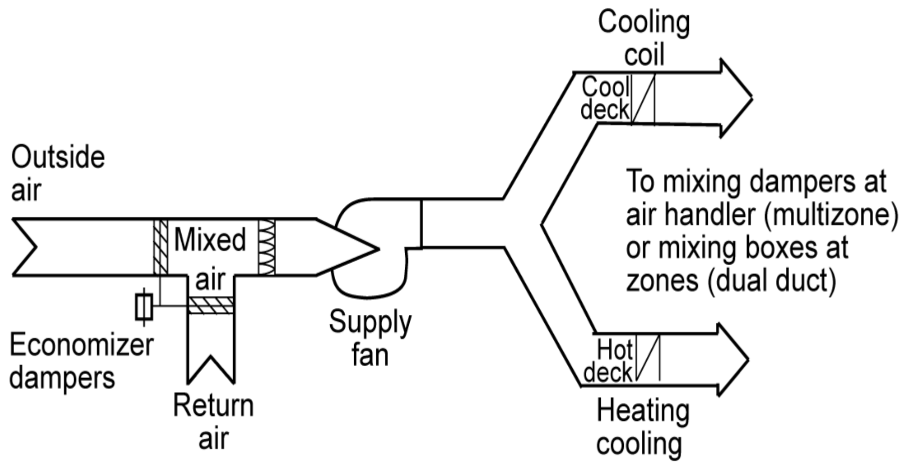


Figure 4-28: Single-Fan Dual-Duct System



Example 4-36

Question

If the design conditions are 94 degrees F db/82 degrees F wb can the design cooling loads to size a water-side economizer?

Answer

No. The design cooling load calculations must be rerun with the outdoor air temperature set to 50 degrees F db/45 degrees F wb. The specified tower, as well as cooling coils and other devices, must be checked to determine if it has adequate capacity at this lower load and wet-bulb condition.

Example 4-37

Question

Will a strainer cycle water-side economizer meet the prescriptive economizer requirements? (Refer to Figure 4-36)

Answer

No. It cannot be integrated to cool simultaneously with the chillers.

Example 4-38

Question

Does a 12-ton packaged AC unit in climate zone 10 need an economizer?

Answer

Yes. In addition, the economizer must be equipped with a fault detection and diagnostic system. However, the requirement for an economizer can be waived if the AC unit's efficiency is greater than or equal to an EER of 14.3. Refer to Table 4-18.

4.6.2.3 Variable Air Volume (VAV) Supply Fan Controls

§140.4(c) and §140.4(m)

Both single and multiple zone systems are required to have VAV supply based on the system type as described in Table 4-21. Single zone equipment in specific CZs must be HPs and when greater than 5 tons must be VAV. The VAV requirements for supply fans are as follows:

1. Single zone systems (where the fans are controlled directly by the space thermostat) shall have a minimum of two stages of fan speed with no more than 66 percent speed when operating on stage one while drawing no more than 40 percent full fan power when running at 66 percent speed.
2. All systems with air-side economizers to satisfy Section 4.5.2.2 are required to have a minimum of 2 speeds of fan control during economizer operation.
3. Multiple zone systems shall limit the fan motor demand to no more than 30 percent of design wattage at 50 percent design air volume.

Variable speed drives can be used to meet any of these three requirements.

Actual fan part-load performance, available from the fan manufacturer, should be used to test for compliance with item 3 above. Figure 4-28 shows typical performance curves for different types of fans. Both air foil fans and backward inclined fans using either discharge dampers or inlet vanes consume more than 30 percent power at 50 percent flow (when certified manufacturer's test data shows static pressure set point is one-third of total design static pressure). These fans will not normally comply with these requirements unless a variable speed drive is used.

VAV fan systems that do not have DDC to the zone level are required to have the static pressure sensor located in a position such that the control set point is less than or equal to 1/3 of the design static pressure of the fan. For systems without static pressure reset, the further the sensor is from the fan the more energy will be saved. For systems with multiple duct branches in the distribution separate sensors in each branch must be provided to control the fan and to satisfy the sensor with the greatest demand. When locating sensors, care should be taken to have at least one sensor between the fan and all operable dampers (e.g., at the bottom of a supply shaft riser before the floor fire/smoke damper) to prevent loss of fan static pressure control.

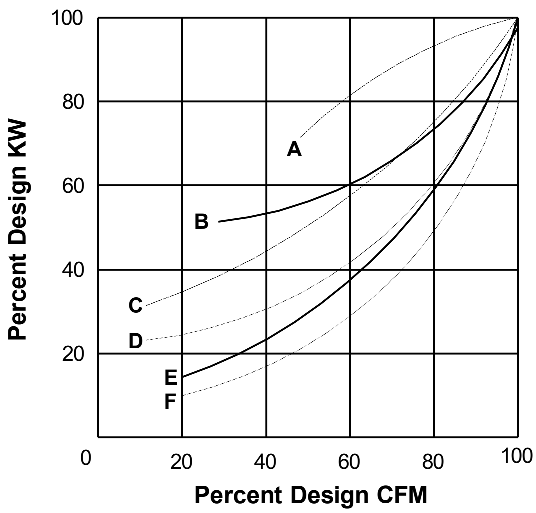
For systems with DDC to the zone level the sensor(s) may be anywhere in the distribution system and the duct static pressure set point must be reset by the zone demand. Typically, this is done by one of the following methods:

1. Controlling so that the most open VAV box dampers are 95 percent open.
2. A trim and respond algorithm to continually reduce the pressure until one or more zones indicate that they are unable to maintain airflow rate set points.

3. Other methods that dynamically reduce duct static pressure setpoint as low as possible while maintaining adequate pressure at the VAV box zone(s) of greatest demand.

Reset of supply pressure by demand not only saves energy but it also protects fans from operation in surge at low loads. Chapter 13, Acceptance Requirements, describes mandated acceptance test requirements for VAV system fan control.

Figure 4-29: VAV Fan Performance Curve



A. Air foil or backward inclined centrifugal fan with discharge dampers

B. Air foil centrifugal fan with inlet vanes

C. Forward curved centrifugal fan with discharge dampers or riding curve

D. Forward curved centrifugal fan with inlet vanes

E. Vane-axial fan with variable pitch blades

F. Any fan with variable speed drive (mechanical drives will be slightly less efficient)

Table 4-21: Fan Control Systems

Cooling System Type	Fan Motor Size	Cooling Capacity
DX Cooling	any	≥ 65,000 Btu/hr
Chilled Water and Evaporative	≥ 1/4 HP	any

Source: California Energy Commission, Building Energy Efficiency Standards, Table 140.4-D

4.6.2.4 Supply-Air Temperature Reset Control

§140.4(f) and §170.2(c)4D

Mechanical space-conditioning systems supplying heated or cooled air to multiple zones must include controls that automatically reset the supply-air temperature in response to representative building loads or to outdoor air temperature. The controls must be capable of resetting the supply-air temperature by at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

For example, if the design supply temperature is 55 degrees F and the design room temperature is 75 degrees F, then the difference is 20 degrees F, of which 25 percent is 5 degrees F. Therefore, the controls must be capable of resetting the supply temperature from 55 degrees F to 60 degrees F.

Air distribution zones that are likely to have constant loads, such as interior zones, shall have airflow rates designed to meet the load at the fully reset temperature. Otherwise, these zones may prevent the controls from fully resetting the temperature or will unnecessarily limit the hours when the reset can be used.

Supply air reset is required for VAV reheat systems even if they have variable-speed drive (VSD) fan controls. The recommended control sequence is to lead with supply temperature set point reset in cool weather where reheat might dominate the equation and to keep the chillers off as long as possible. Thereafter the system can return to a fixed low set point in warmer weather when the chillers are likely to be on. During reset a demand-based control is employed that uses the warmest supply air temperature to satisfy all of the zones in cooling.

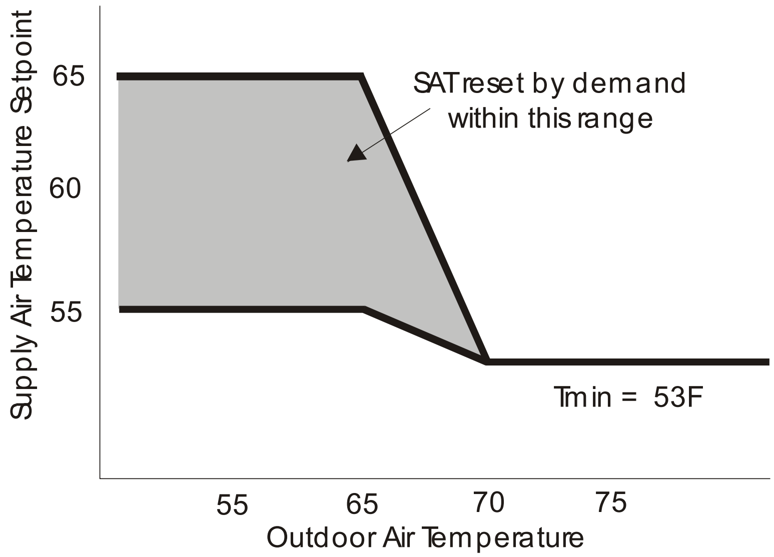
This sequence is described as follows: during occupied mode the set point is reset from
T-min (53 degrees F) (when the outdoor air temperature is 70 degrees F and above) proportionally up to T-max (when the outdoor air temperature is 65 degrees F and below). T-max shall range from 55 degrees F to 65 degrees F and shall be the output of a slow reverse-acting proportional-integral loop that maintains the cooling loop of the zone served by the system with the highest cooling loop at a set point of 90 percent (See Figure 4-30).

Supply temperature reset is also required for constant volume systems with reheat justified on the basis of special zone pressurization relationships or cross-contamination control needs.

Supply-air temperature reset is not required when:

1. The zone(s) must have specific humidity levels required to meet exempt process needs. Computer rooms cannot use this exception.
2. Where it can be demonstrated (to the satisfaction of the enforcement agency) that supply air reset would increase overall building energy use.
3. The space-conditioning zone has controls that prevent reheating and recooling and simultaneously provide heating and cooling to the same zone.
4. Systems serving healthcare facilities.

Figure 4-30: Energy Efficient Supply Air Temperature Reset Control for VAV Systems



Recommended Supply Air Temperature Reset Method

4.6.2.5 Heat Rejection Fan Control

§140.4(h) and §170.2(c)4E

When the fans on cooling towers, closed-circuit fluid coolers, air-cooled condensers and evaporative condensers are powered by a fan motor of 7.5 hp or larger, the system must be capable of operating at two-thirds speed, or less. In addition, the system must have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature or pressure of the heat rejection device. Fan speed controls are exempt when:

1. Fans are powered by motors smaller than 7.5 hp.
2. Heat rejection devices are included as an integral part of the equipment listed in Table 4-1 through Table 4-11.
3. Condenser fans serving multiple refrigerant circuits or flooded condensers.
4. Up to one third of the fans on a condenser or tower with multiple fans have lead fans that comply with the speed control requirement.

Example 4-39

Question

A chilled water plant has a three-cell tower with 10 hp motors on each cell. Are speed controls required?

Answer

Yes. At minimum the designer must provide 2-speed motors, pony motors or variable speed drives on two

of the three fans for this tower.

4.6.2.6 Hydronic System Measures

§140.4(k) and §170.2(c)4I

A. Hydronic Variable Flow Systems

§140.4(k)1 and §170.2(c)4Ii

Hot water and chilled-water systems are required to be designed for variable flow. Variable flow is provided by using 2-way control valves. The Energy Code only require that flow is reduced to whichever value is greater: 50 percent or less of design flow or the minimum flow required by the equipment manufacturer for operation of the central plant equipment.

There are two exceptions for this requirement:

1. Systems that include no more than three control valves.
2. Systems having a total pump system power less than or equal to 1.5 hp.

It is not necessary for each individual pump to meet the variable flow requirement. These requirements can be met by varying the total flow for the entire pumping system in the plant. Strategies that can be used to meet these requirements include but are not limited to variable frequency drives on pumps and staging of the pumps.

The primary loop on a primary/secondary or primary/secondary/tertiary system could be designed for constant flow even if the secondary or tertiary loop serves more than three control valves. This is allowed because the primary loop does not directly serve any coil control valves. However, the secondary and tertiary loops of these systems must be designed for variable flow if they have four or more control valves.

The flow limitations are provided for primary-only variable flow chilled-water systems where a minimum flow is typically required to keep a chiller on-line. In these systems minimum flow can be provided with either a bypass with a control valve or some three-way valves to ensure minimum flow at all times. The system with a bypass valve is more efficient as it only provides bypass when absolutely required to keep the plant online.

For hot water systems, application of slant-tube or bent tube boilers will provide the greatest flow turndown. Typically, copper fin tube boilers require a higher minimum flow.

Example 4-40

Question

A plant is trying to meet the variable flow requirements of Section 4.5.2.6. Must each individual pump meet these requirements for the plant to comply with the Energy Code?

Answer

No. Individual pumps do not need to meet the variable flow requirements of this section. As long as the entire plant meets the variable flow requirements, the plant is in compliance. For example, the larger pumps may be equipped with variable frequency drives, or the pumps can be staged in a way that can meet these requirements.

B. Isolation for Chillers and Boilers

§140.4(k)2 and 3 and §170.2(c)4Iii and iii

Plants with multiple chillers or boilers are required to provide either isolation valves or dedicated pumps. In addition, they must check valves to ensure that flow will only go through the chillers or boilers that are staged on. Chillers that are piped-in series for the purpose of increased temperature differential shall be considered as one chiller.

C. Chilled and Hot Water Reset

§140.4(k)4 and §170.2(c)4Iiv

Similar to the requirements for supply air temperature reset, chilled and hot water systems that have a design capacity greater than 500,000 Btu/h are required to provide controls to reset the hot or cold-water temperature set points as a function of building loads or the outdoor air temperature. This reset can be achieved either using a direct indication of demand (usually cooling or heating valve position) or an indirect indication of demand (typically outdoor air temperature). On systems with DDC controls reset using valve position is recommended.

Exceptions for this requirement:

1. Hydronic systems that are designed for variable flow complying with §140.4(k)1
2. Systems serving healthcare facilities

D. Isolation Valves for Water-Loop Heat Pump Systems

§140.4(k)5 and §170.2(c)4Iv

Water-circulation systems serving water-cooled air conditioner and hydronic heat pump systems with a design circulation pump brake horsepower greater than five bhp are required to be provided with 2-way isolation valves that close whenever the compressor is off. These systems are also required to be provided with the variable speed drives and pressure controls described in the following section.

Although not required on central tenant condenser water systems (for water-cooled AC units and HPs) it is beneficial to provide the 2-way isolation valves on these systems as well. In addition to providing pump energy savings, these two-way valves can double as head-pressure control valves allowing aggressive condenser water to reset for energy savings in chilled water plants that are also cooled by the towers.

E. Variable-Speed Drive for Pumps Serving Variable-Flow Systems

§140.4(k)6 and §170.2(c)4Ivi

Pumps on variable flow systems that have a design circulation pump brake horsepower greater than 5 bhp are required to have variable-speed drives. Alternatively, they may have a different control that will result in pump motor demand of no more than 30 percent of design wattage, at 50 percent of design water flow.

Pressure Sensor Location and Set point

1. For systems without direct-digital control of individual coils reporting to the central control panel, differential pressure must be measured at the most remote heat exchanger or the heat exchanger requiring the most pressure. This includes chilled-water systems, condenser water systems serving water-cooled air conditioning loads and water-loop heat pump systems.
2. For systems with direct digital control of individual coils with a central control panel, the static pressure set point must be reset based on the valve requiring the most pressure and the set point shall be no less than 80 percent open. The pressure sensor(s) may be mounted anywhere.

Exceptions are provided for hot-water systems and condenser water systems that only serve water-cooled chillers. The hot water systems are exempted because the heat from the added energy of the pump riding the curve provides a beneficial heat that reduces the boiler use. This diminishes the benefit from the reduced pumping energy.

F. Hydronic Heat Pump (WLHP) Controls

§140.4(k)7 and §170.2(c)4Ivii

Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection and heat addition must have controls that are capable of providing a heat pump water supply temperature dead band of at least 20 degrees F between initiation of heat rejection and heat addition by the central devices. Exceptions are provided where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 20 degrees F shall be allowed.

4.6.2.7 Window/Door Switches for Mechanical System Shutoff

§140.4(n) and §170.2(c)4L

If a directly conditioned zone has a thermostat and one or more manually operable wall or roof openings to the outdoors, then the openings must all have sensors that communicate to the HVAC system. The HVAC controller must be capable of shutting off the heating or cooling to that zone if the sensor detects that the opening has remained open for more than five minutes. This can be accomplished by resetting the heating set point to 55 degrees F or the heating can be disabled altogether. If the HVAC system is in cooling mode, then similarly this requirement can be satisfied by resetting the cooling set point to 90 degrees F -unless the outside air temperature is less than the space temperature, in which case the cooling set point can be reset, or not. If the zone is in cooling and the outside air temperature is less than the space temperature, then additional infiltration from the opening provides economizer-free cooling and is not an additional cooling load on the mechanical system.

This requirement does not require any openings to the outdoors to.be operable. However, if operable openings are present, then they must comply with this requirement.

Mechanical ventilation as required by Section 4.3.2 must still be provided. The mechanical system shut off pertains to the space conditioning equipment only. Mechanical ventilation must still be provided if the space does not fall under the natural ventilation criteria. Systems that meet the ventilation requirements with natural ventilation, rather than mechanical ventilation, are not exempt from the window/door switch requirement. Thus, in the same way that most homeowners typically choose between opening the windows and running the heating/cooling, window/door switches will now cause occupants to choose between opening windows/doors and allowing full heating/cooling.

Manually operable openings to the outdoors include manually operable windows, skylights, and doors that do not have automatic closing devices (e.g., sliding balcony doors). Motorized openings (e.g., motorized skylights) are still considered manually operable if occupants can move the openings as desired and they will stay open until manually closed.

If a zone serves more than one room, then only the openings in the room with the thermostat are required to be interlocked. For example, if three perimeter private offices are served by a single VAV box then only the operable openings in the office with the thermostat need to be interlocked. The windows in the offices that do not have a thermostat do not need to be interlocked.

If there is a large room with more than one zone, then only the zones with operable windows in them need to be interlocked. For example, if a large open office has a perimeter zone and an interior zone in the same room and there are operable windows in the perimeter zone but not the interior zone then only the perimeter zone thermostat needs to be interlocked to the windows.

Exceptions to this requirement:

1. Interlocks are not required on doors with automatic closing devices
2. Any space without a thermostatic control
3. Healthcare facilities

Alterations to existing buildings are exempt from this requirement. Additions to existing buildings only have to comply if the operable opening(s) and associated zone are new.

4.6.3 Acceptance Requirements

There are a number of acceptance requirements related to control systems. These include:

1. Automatic time switch control devices
2. Constant volume package unit
3. Air-side economizers
4. VAV supply fan controls
5. Hydronic-system controls

These tests are described in Chapter 13 as well as the Reference Nonresidential Appendix NA7.

4.7 HVAC System Requirements

There are no acceptance tests for these requirements.

4.7.1 Mandatory Requirements

4.7.1.1 Water-Conservation Measures for Cooling Towers

§110.2(e)

There are mandatory requirements (§110.2[e]) for the efficient use of water in the operation of open (direct) and closed (indirect) cooling towers. The building standard applies to the new construction and retrofit of commercial, industrial, and institutional cooling towers with a rated capacity of 150 tons or greater. For these towers all of the following are required:

1. The towers shall be equipped with either conductivity or flow-based controls to manage cycles of concentration based on local water quality conditions. The

controls shall automate system bleed and chemical feed based on conductivity, or in proportion to metered makeup volume, metered bleed volume, recirculating pump run time, or bleed time. Where employed, conductivity controllers shall be installed in accordance with manufacturer's specifications.

2. Design documents have to document maximum achievable cycles of concentration based on local water supply as reported by the local water supplier, and using a calculator approved by the Energy Commission. The calculator shall determine maximum cycles based on a Langelier Saturation Index (LSI) of 2.5 or less. An approved calculator can be downloaded from the Energy Commission's website: http://www.energy.ca.gov/title24/2019standards/documents/maximum_cycles_calculator.xls
3. The towers shall be equipped with a flow meter with an analog output for flow. This can be connected to the water treatment control system using either a hardwired connection or gateway.
4. The towers shall be equipped with an overflow alarm to prevent overflow of the sump in case of makeup water valve failure. This requires either a water level sensor or a moisture detector in the overflow drain. The alarm contact should be connected to the building Energy Management Control System to initiate an alarm to alert the operators.
5. The towers shall be equipped with drift eliminators that achieve a maximum rated drift of 0.002 percent of the circulated water volume for counter-flow towers and 0.005 percent for crossflow towers.

As water is evaporated off the tower, the concentration of dissolved solids, like calcium carbonate and silica, will increase. The pH of the water will also change. With high levels of silica, or dissolved solids, deposits will form on the tower fill or clog the tower nozzles, which will reduce the tower's heat rejection capacity. High pH is a concern for metal tower basins and structural members. As the thresholds of these contaminants of concern are approached the automated controls should bleed some of the concentrated water out and dilute it with make-up water. The bleed can be controlled by measurement of make-up water flow (an indirect measurement of water drift and evaporation) or through conductivity (a measurement of the dissolved solids). The term "*cycles of concentration*" is the metric of how concentrated the contaminants are at the controlled level. The right value depends on the characteristics of the supply water, the rate of tower drift, the weather characteristics, and the load on the tower. Good practice involves maintaining the following levels:

- Silica levels should be maintained at less than or equal to 150 ppm
- The Langelier Saturation Index should be maintained at less than or equal to 2.5 (see explanation below)

- The pH in new cooling towers using galvanized metal should be maintained at less than or equal to 8.3 until metal is passivated, which occurs after three-six months of operation

To meet compliance, an Energy Commission approved calculator (NRCC-MCH-06-E) allows the building owner to enter water quality parameters – including conductivity, alkalinity, calcium hardness, magnesium hardness, and silica. These values are available from the local water supplier in the most recent annual Consumer Confidence Report or Water Quality Report. These reports are generally posted on the water supplier's website, or by contacting the local water supplier by telephone. Many water districts have multiple sources of water which often are changed seasonally. For example, many water districts use a reservoir in the winter and spring then switch to well water in the summer and fall. Each supply will typically have different characteristics; the water treatment and control cycles of concentration should be seasonally shifted as well.

After entering the required water quality data, the user must also enter skin temperature; the default value of 110 degrees F is acceptable. Lastly, target tower cycles of concentration are entered into the calculator. The calculator computes the LSI based on the cycles of concentration entered by the user. The maximum value of the index is 2.5. Therefore, the user should enter the highest cycles of concentration value in 0.10 units that results in a calculated LSI not to exceed 2.5. The resulting cycles of concentration are considered by the Energy Commission to be the Maximum Achievable Cycles of Concentration and must be recorded on the mechanical compliance document (NRCC-MCH-06-E), to which a copy of the Consumer Confidence Report or Water Quality Report must be attached. The professional engineer of record must sign the compliance document (NRCC-MCH-06-E) attesting to the calculated maximum cycles of concentration.

Example 4-41

Question

What is the Langelier Saturation Index?

Answer

The Langelier Saturation Index predicts scaling. It indicates whether water will precipitate, dissolve, or be in equilibrium with calcium carbonate. The index is a function of hardness, alkalinity, conductivity, pH, and temperature expressed as the difference between the actual system pH and the saturation pH.

Example 4-42

Question

Where is the data for makeup water quality?

Answer

Water agencies are required to make their annual water quality data available to the public. Water quality data is generally organized into an annual Consumer Confidence Report or Water Quality Report, which can often be found posted on the water agency's website by searching for the key words "water quality". Since many water districts have more than one water supply ask for a report for each source.

Example 4-43

Question

What if all, or some, of the water quality data is not provided in the Consumer Confidence Report or Water Quality Report?

Answer

Some data may be available by calling the local water agency's Water Quality Division. For example, agencies are not required to test for and report alkalinity. However, they often do test for it and will provide data over the phone or in an email. Also check with water treatment firms that are doing business in the area. They often have test data that they will share. Finally, it is possible to hire a water treatment firm to take samples of the water to test.

4.7.2 Prescriptive Requirements

4.7.2.1 Sizing and Equipment Selection

§140.4(a)1 and §170.2(c)

The Energy Code requires mechanical heating and cooling equipment (including electric heaters and boilers) serving common use areas in multifamily buildings, hotel/motel buildings, and nonresidential buildings other than healthcare facilities to be the smallest size available, while still meeting the design heating and cooling loads of the building or spaces being served. Depending on the equipment, oversizing can be either a penalty or benefit to energy usage. For vapor compression equipment, gross oversizing can drastically increase the energy usage and in some cases cause premature failure from short cycling of compressors. Boilers and water-heaters generally suffer lower efficiencies and higher standby losses if they are oversized. On the other hand, cooling towers, cooling coils, and variable speed driven cooling tower fans can actually improve in efficiency if oversized. Oversized distribution ductwork and piping can reduce system pressure losses and reduce fan and pump energy.

When equipment is offered in size increments, such that one size is too small and the next is too large, the larger size may be selected.

Mechanical heating and mechanical cooling equipment serving healthcare facilities shall be sized to meet the design heating and cooling loads of the building or facility being served. Packaged HVAC equipment may serve a space with substantially different heating and cooling loads. The unit size should be selected on the larger of the loads, based on either capacity or airflow. The capacity for the other load should be selected as required to meet the load, or if very small, should be the smallest capacity available in the selected unit. For example, packaged air-conditioning units with gas heat are usually sized on the basis of cooling loads. The furnace is sized on the basis of airflow and is almost always larger than the design heating load.

Equipment may be oversized provided one or more of the following conditions are met:

1. It can be demonstrated (to the satisfaction of the enforcing agency) that oversizing will not increase building source energy use
2. Oversizing is the result of standby equipment that will operate only when the primary equipment is not operating. Controls must be provided that prevent the standby equipment from operating simultaneously with the primary equipment
3. Multiple units of the same equipment type are used, each having a capacity less than the design load. In combination, however, the units have a capacity greater than the design load. Controls must be provided to sequence or otherwise optimally control the operation of each unit based on load.

4.7.2.2 Single Zone Space Conditioning System Type

§140.4(a)2

For prescriptive compliance the Energy Code requires single zone space conditioning systems with direct expansion cooling with rated cooling capacity 240,000 Btu/hr or less serving the following spaces to meet the following requirements.

1. Retail and Grocery Building Spaces in climate zones 2 through 15. The space conditioning system shall be a heat pump.
2. Retail and Grocery Building Spaces in climate zones 1 and 16 with cooling capacity less than 65,000 Btu/hr. The space conditioning system shall be an air conditioner with furnace.
3. Retail and Grocery Building Spaces in climate zones 1 and 16 with cooling capacity 65,000 Btu/hr or greater. The space conditioning system shall be a dual-fuel heat pump.
4. School Building Spaces. For climate zones 2 through 15, the space conditioning system shall be a heat pump. For climate zones 1 and 16, the space conditioning system shall be a dual-fuel heat pump.
5. Office, Financial Institution, and Library Building Spaces in climate zones 1 through 15. The space conditioning system shall be a heat pump.
6. Office, Financial Institution, and Library Building Spaces in climate zones 16 with cooling capacity less than 65,000 Btu/hr. The space conditioning system shall be an air conditioner with furnace.

7. Office, Financial Institution, and Library Building Spaces in climate zones 16 with cooling capacity 65,000 Btu/hr or greater. The space conditioning system shall be a dual-fuel heat pump.
8. Office Spaces in Warehouses. The space conditioning system shall be a heat pump in all climate zones.

Any space types not listed above are not subject to the requirements of §140.4(a)2, but shall comply with the other applicable requirements of §140. Also, all other system types, including systems with rated cooling capacity greater than 240,000 Btu/hr, multi-zone systems, and systems using central boilers or chillers, are not subject to the requirements of §140.4(a)2, but shall comply with the other applicable requirements of Section 140. For performance compliance, the prescriptive requirements in §140.4(a)2 set the standard design space conditioning budget. Under performance compliance the building can comply using any supported space conditioning system type as long as it meets the standard design source energy and TDV energy budgets for the building.

4.7.2.3 Load Calculations

§140.4(b) and §170.2(c)2

For the purposes of sizing HVAC equipment, the designer shall use all of the following criteria for load calculations:

1. The heating and cooling system design loads must be calculated in accordance with the procedures described in the ASHRAE Handbook, Fundamentals Volume, Chapter 30, Table 1. Other load calculation methods (e.g., ACCA, SMACNA) are acceptable provided that the method is ASHRAE-based. When submitting load calculations of this type, the designer must accompany the load calculations with a written affidavit certifying that the method used is ASHRAE-based. If the designer is unclear as to whether or not the calculation method is ASHRAE-based, the vendor or organization providing the calculation method should be contacted to verify that the method is derived from ASHRAE. For systems serving healthcare facilities, the method in the California Mechanical Code shall be used.
2. Indoor design conditions of temperature and relative humidity for general comfort applications are not explicitly defined. Designers are allowed to use any temperature conditions within the “comfort envelope” defined by ANSI/ASHRAE 55-1992 or the 2017 ASHRAE Handbook, Fundamentals Volume. Winter humidification or summer dehumidification is not required. For systems serving healthcare facilities, the method in Section 320.00 of the California Mechanical Code shall be used.
3. Outdoor design conditions shall be selected from Reference Joint Appendix JA2, which is based on data from the ASHRAE Climatic Data for Region X, for the following design conditions:

a. Heating design temperatures shall be no lower than the temperature listed in the Heating Winter Median of Extremes value.

b. Cooling design temperatures shall be no greater than the 0.5 percent Cooling Dry Bulb and Mean Coincident Wet Bulb values.

c. Cooling design temperatures for cooling towers shall be no greater than the 0.5 percent cooling design wet bulb values.

For systems serving healthcare facilities, the method in Section 320.0 of the California Mechanical Code shall be used.

4. Outdoor air ventilation loads must be calculated using the ventilation rates required in Section 4.3.
5. Envelope heating and cooling loads must be calculated using envelope characteristics including square footage, thermal conductance, solar heat gain coefficient or shading coefficient and air leakage, consistent with the proposed design.
6. Lighting heating or cooling loads shall be based on actual design lighting levels or power densities consistent with Chapter 5.
7. People sensible and latent gains must be based on the expected occupant density of the building and occupant activities as determined under Section 4.3. If ventilation requirements are based on a cfm/person basis, then people loads must be based on the same number of people as ventilation. Sensible and latent gains must be selected for the expected activities as listed in 2017 ASHRAE Handbook, Fundamentals Volume, Chapter 18.
8. Loads caused by a process shall be based on actual information (not speculative) on the intended use of the building.
9. Miscellaneous equipment loads include such things as duct losses, process loads and infiltration and shall be calculated using design data compiled from one or more of the following sources:

   a. Actual information based on the intended use of the building

   b. Published data from manufacturer's technical publications or from technical societies (such as the ASHRAE Handbook, HVAC Applications Volume)

   c. Other data based on the designer's experience of expected loads and occupancy patterns

10. Internal heat gains may be ignored for heating load calculations.
11. A safety factor of up to 10 percent may be applied to design loads to account for unexpected loads or changes in space usage.

12. Other loads such as warm-up or cool-down shall be calculated using one of the following methods:

    a. A method using principles based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time

    b. The steady state design loads may be increased by no more than 30 percent for heating and 10 percent for cooling. The steady state load may include a safety factor of up to 10 percent as discussed above in Item 11.

13. The combination of safety factor and other loads allows design cooling loads to be increased by up to 21 percent (1.10 safety x 1.10 other), and heating loads by up to 43 percent (1.10 safety x 1.30 other).

Example 4-44

Question

Do the sizing requirements restrict the size of duct work, coils, filter banks, etc. in a built-up system?

Answer

No. The intent of the Energy Code is to limit the size of equipment, which if oversized will consume more energy on an annual basis. Coils with larger face areas will usually have lower pressure drops than otherwise and may also allow the chilled water temperature to be higher, both of which may result in a decrease in energy usage. Larger filter banks will also usually save energy. Larger duct work will have lower static pressure losses, which may save energy, depending on the duct’s location, length, and degree of insulation.

Oversizing fans, on the other hand, may or may not improve energy performance. An oversized airfoil fan with inlet vanes will not usually save energy, as the part-load characteristics of this device are poor. But the same fan with a variable frequency drive may save energy. Controls are also an important part of any system design.

The relationship between various energy consuming components may be complex and is left to the designer’s professional judgment. When components are oversized, it must be demonstrated to the satisfaction of the enforcement agency that energy usage will not increase.

4.7.2.4 Fan Power Consumption

§140.4(c) and §170.2(c)4

Maximum fan power is regulated in individual fan systems where the power of at least one fan or fan array in the fan system is greater than or equal to 1kW of fan electrical input power at design conditions (see Section 4.10 for definitions). A system consists of only the components that must function together to deliver air to a given area; fans that can operate independently of each other comprise separate systems. Included are all fans associated with moving air from a given space-conditioning system to the conditioned spaces and back to the source, or to exhaust air to the outdoors.

The 1kW total criteria apply to:

1. All supply and return fans within the space-conditioning system that operate at peak load conditions.
2. All exhaust fans at the system level that operate at peak load conditions. Exhaust fans associated with economizers are not counted, provided they do not operate at peak conditions, including fans that circulate air for the purpose of conditioning air within the space.
3. Fan-powered VAV boxes if these fans run during the cooling peak. This is always the case for fans in series type boxes. Fans in parallel boxes may be ignored if they are controlled to operate only when zone heating is required, are normally off during the cooling peak, and there is no design heating load, or they are not used during design heating operation.
4. Elevator equipment room exhausts (or other exhausts that draw air from a conditioned space) through an otherwise unconditioned space, to the outdoors.

The criteria are applied individually to each space-conditioning system. In buildings having multiple space-conditioning systems, the criteria apply only to the systems having a fan or fan array whose demand exceeds 1 kW of fan electrical input power.

Fans not directly associated with moving conditioned air to or from the space-conditioning system, or fans associated with a process within the building.

Meeting the fan power limit is accomplished in two parts. First, the designer calculates the allowable fan input power for their fan systems (Fan kWbudget). Second, the designer calculates the actual electrical input power (Fan kWdesign, system) values of the fans in the system by summing up the Fan kWdesign value of each fan in the fan system. The total power input must be less than the allowable power input for the fan system to comply.

To calculate the fan kW budget, the designer must know the following pieces of information:

5. The type of fan system (described below)
6. The fan system control type (i.e., either Multi-Zone VAV or all other fan systems) and airflow passing through each component of the fan system
7. Knowledge of the status of all components (e.g., presence or absence of DX cooling coils, gas furnace, energy recovery wheel, economizer return damper, etc.) in the fan system. This determines which allowances from the given allowance table (e.g., Table 140.4-A, Table 140.4-B, etc.) apply to the fan system when calculating Fan kWbudget.

8. The altitude of the building to account for reduced air density (if greater than 3,000 feet).

The fan system type contributes to the determination of how the fan power budget is calculated. The fan system types are listed and described below.

1. **Single-cabinet fan system.** This is a fan system where a single fan, single fan array, a single set of fans operating in parallel, or fans or fan arrays in series and embedded in the same cabinet that both supply air to a space and recirculate the air. Designers of this type of system will use the applicable allowances from the given supply fan power allowance table (e.g., Table 140.4-A) and exhaust/return/relief/transfer fan power allowance table (e.g., Table 140.4-B) at the fan system design airflow.

   Examples include:

   - A rooftop unit with a single fan that both supplies air to the space and recirculates air.
   - An air handler with a supply and return fan in the same cabinet.
   - A rooftop unit with a relief fan that only runs during economizer operation.

2. **Supply-only fan system.** This is a fan system that provides supply air to interior spaces and does not recirculate the air. Designers of this type of system will use the applicable allowances from the given supply table (e.g., Table 140.4-A) at the fan system design supply airflow.

   Examples include:

   - An air handler with only a supply fan where the return fan is not in the same cabinet.
   - The supply fan of an ERV, even if there is an exhaust fan in the same cabinet.
   - The fan of a make-up air unit where air is exhausted from the building by a different fan.

3. **Relief fan system.** This is a fan system dedicated to the removal of air from interior spaces to the outdoors that operates only during economizer operation. Designers of this type of system will use the applicable allowances from the given exhaust/return/relief/transfer fan power allowance table (e.g., Table 140.4-B) at the fan system design relief airflow.

4. **Exhaust, return, and transfer fan systems.** An exhaust fan system is a fan system dedicated to the removal of air from interior spaces to the outdoors that may operate at times other than economizer operation. A return fan system is a fan system dedicated to removing air from interior where some or all the air is to be recirculated except during economizer

operation. A transfer fan system is a fan system that exclusively moves air from one occupied space to another. Designers of any of these three system types will use the applicable allowances from the given exhaust/return/relief/transfer fan power allowance table (e.g., Table 140.4-B) at the fan system design airflow.

5. **Complex fan system.** This is a fan system that combines a single-cabinet fan system with other supply fans, exhaust fans, or both. The designer will separately calculate the fan power allowance for the supply component and then return/exhaust component, and then arrive at a total fan power allowance. This approach differs from a single-cabinet fan system in that for the single-cabinet fan system, the individual allowances from the supply and exhaust/return/relief/transfer tables are added before arriving at a Fan kW budget value, whereas for complex fan systems, a supply power allowance value is calculated using its allowances, a return/exhaust power value is calculated using its allowances, and then the two are added together to determine the overall Fan kW budget value.

Once the required information and fan system classification has been determined, the designer will apply the appropriate allowances from the appropriate budget table before calculating the overall Fan kWbudget value. All fan systems should use the base allowance from the applicable table, as well as other allowances that apply to their individual fan system. For fan system components that only receive a fraction of the airflow passing through the rest of the system, the adjusted fan power allowance should be calculated according to the following formula.

$$FPA_{adj} = \frac{Q_{comp}}{Q_{sys}} \times FPA_{comp}$$

Where

FPA_{adj} = The corrected fan power allowance for the component in w/cfm

Q_{comp} = The airflow through component in cfm

Q_{sys} = The fan system airflow in cfm

FPA_{comp} = The fan power allowance of the component from the applicable table (e.g., Table 140.4-A or Table 140.4-B)

If the site is at an altitude of 3,000 feet above sea level or greater, the designer should apply the appropriate correction factor from Table 140.4-C to the resulting Fan kWbudget value.

Fan electrical input power (Fan kWdesign) is the electrical input power in kilowatts required to operate an individual fan or fan array at design conditions. It includes the power consumption of motor controllers, if present. This value encompasses all wire-to-air losses, including motor controller, motor, and belt losses.

There are four methods available to determine Fan kWdesign for an individual fan in a fan system. There is no requirement to use the same method for different fans in the fan system. For all methods, fan input power shall be calculated with twice the clean filter pressure drop.

1. Use the default values for Fan kWdesign (Table 140.4-D in the standard) based on minimum U.S. DOE motor efficiencies. There are values for input power with and without a motor controller. This method can be used if only the motor nameplate horsepower is known. This table will likely provide a conservative estimate of fan input electrical power. This method cannot be used for complex fan systems.
2. Use the fan input power at fan system design conditions provided by the manufacturer of the fan, fan array, or equipment that includes the fan or fan array calculated per a test procedure included in USDOE 10 CFR 430, USDOE 10 CFR 431, ANSI/AMCA Standard 208, ANSI/AMCA Standard 210, AHRI Standard 430:2020, AHR Standard 440:2019 and ISO 5801:2017.
3. Use one of the options listed in Section 5.3 of ANSI/AMCA Standard 208 at design conditions. This method can be used in cases where the fan shaft input power is provided by the manufacturer, and the designer needs to calculate the input power to the motor or motor controller.
4. Use the maximum electrical input power included on the fan motor nameplate. Note that this value does not account for the loading of the fan in question (which will usually be lower than this value) and thus is likely to be a conservative method.

Once the designer has calculated the fan power budget value (Fan kWbudget) and their fan system's input electrical power at design conditions (Fan kWdesign, system), the two values are compared against each other to determine if the fan system complies.

$$Fan\ kW_{design,system} \leq Fan\ kW_{budget}$$

If the above inequality is valid, then the fan system complies with the fan power budget.

4.7.2.5 Selected Fan Power Budget Allowance

The types of devices listed in Table 4-22 that qualify for additional fan power are as follows:

1. **Return or exhaust systems required by code or accreditation standards to be fully ducted, or systems required to maintain air pressure differentials between adjacent rooms.** The basic input power allowance is based on the assumption that return air passes through an open plenum on its way back to the fan system. For systems where all of the return air is ducted back to the return, an additional allowance equivalent to

a pressure drop of 0.5 inches of water is allowed. This allowance may not be applied for air systems that have a mixture of ducted and non-ducted return.

2. **Return and/or exhaust airflow control devices required for space pressurization control.** Some types of spaces, such as laboratories, test rooms, and operating rooms, require that an airflow control device be provided at both the supply air delivery point and at the exhaust. The exhaust airflow control device is typically modulated to maintain a negative or positive space pressure relative to surrounding spaces. An additional pressure drop and associated input power adjustment are permitted when this type of device is installed. The allowance may be taken when some spaces served by an air handler have exhaust airflow devices and other spaces do not. However, the allowance is taken only for the cfm of air that is delivered to spaces with a qualifying exhaust airflow device.

3. **Exhaust filters, scrubbers, or other exhaust treatment.** Some applications require the air leaving the building be filtered to remove dust or contaminants. Exhaust air filters are also associated with some types of heat recovery systems, such as run-around coils. In this application, the purpose of the filters is to help keep the coils clean, which is necessary to maintain the effectiveness of the heat recovery system. When such devices are specified and installed, the pressure drop of the device at the fan system design condition may be included as an allowance. When calculating the additional input power, only consider the volume of air that is passing through the device under fan system design conditions.

4. **Particulate filtration allowance: greater than MERV 16 and electronically enhanced filters.** The primary purpose of filters is to keep the fans, coils, and ducts clean, and to reduce maintenance costs. A secondary purpose is to improve indoor air quality. MERV ratings are used as the basis of this allowance. These ratings indicate the amount of particulate removed from the airstream. A higher MERV rating is more efficient and removes more material. The allowance for filters with a MERV rating of 16 and greater and all electronically enhanced filters is based on two times the clean pressure drop of the filter at fan system design conditions. These clean pressure drop data are taken from manufacturers' literature.

5. **Carbon and other gas-phase air cleaners.** For carbon and other gas-phase air cleaners, additional input power is based on the rated clean pressure drop of the air-cleaning device at fan system design conditions.

6. **Biosafety cabinet.** If the device is listed as a biosafety cabinet, you can use this allowance.

7. **Energy recovery device.** Energy recovery devices exchange heat between the outside air intake stream and the exhaust airstream. There are two common types of heat recovery devices: heat wheels and air-to-air heat

exchangers. Both increase the pressure drop and require a system with a larger input power. The allowance increases linearly with an increasing energy recovery ratio. There are seven rows, but designers can only choose one allowance corresponding to their energy recovery device's energy recovery ratio. The allowance is a function of the enthalpy recovery ratio. This is intended to encourage designers to select energy recovery devices that have low pressure drops and high enthalpy recovery ratios, and thus provide a net energy reduction. This allows systems that have trouble meeting the fan power limit to gain a higher fan power allowance — by using larger energy recovery devices with higher enthalpy recovery ratios.

8. **Coil runaround loop.** The coil runaround loop is a form of energy recovery device that uses separate coils in the exhaust and outdoor air intakes with a pump in between. The allowance is to account for the increased air pressure of these two coils.
9. **Exhaust systems that serve fume hoods.** Exhaust systems that serve fume hoods get an allowance equivalent to an additional 0.35 inches of water to account for the pressure through the fume hood, ductwork, and zone valve or balancing devices. This allowance applies to the exhaust fans only.

Example 4-45

Question

A multi zone VAV reheat system serves a low-rise office building. The building is served by one VAV packaged rooftop unit with a 10 hp supply fan with a VSD. There is a separate return fan, also with a VSD. Four parallel fan-powered VAV terminal units are used on north-facing perimeter offices for heating. Two series fan-powered VAV boxes, each with a 1/3 hp fan with an electronically commutated motor, serve two interior conference rooms.

The space also uses a local exhaust fan for each of the four bathrooms. Fans for the system are listed below. Fan performance is as described in the table below. The fan electrical input power was calculated using motor and VFD (where applicable) efficiency assumptions derived from AMCA 207, which is one of the methods to convert shaft brake horsepower to input electrical power available to designers. The motors were assumed to be 4-pole ODP (open drip proof) with direct drive transmission.

Is this system in compliance with Section 140.4(c)?

Quantity	Fan Service	Design cfm, each	bhp	Nameplate Motor, hp	Input kW per AMCA 207	In Scope?
1	Supply fan with variable-speed drive	12,000	8.7	10	7.35	Yes
2	Condenser fans	9,300	0.7	1	0.64	No - do not move conditioned air
1	Return fan	11,000	4.2	5	3.68	Yes
4	Bathroom exhaust fans	350	0.16	1/5	0.20	No - less than 1 kW
4	Parallel fan-powered VAV boxes	400	0.08	1/5	0.14	No - less than 1 kW
2	Series fan-powered VAV boxes	600	0.12	1/3	0.17	No - <1kW, but deduction applies

Answer

First, determine which fans to include in the nameplate fan system power calculation:

- The supply and return fans are clearly included in the fan power calculation.
- The condenser fans are not included because they circulate outdoor air and do not affect the conditioned air supplied to the space.
- The toilet exhaust fans are included because they each have a fan electrical input power of less than 1 kW.
- The parallel fan powered and series fan-powered VAV boxes are not included in the fan power calculation because they each have a fan electrical input power of less than 1kW. However, the deduction for terminal units < 1 kW will be applied to the series fan-powered boxes. The deduction does not apply to the parallel boxes because their fans do not operate at design conditions.

There are two steps to determine whether the fan system complies with the fan power budget. First, the allowable power must be calculated. Second, the fan electrical power input of the in-scope fans must be compared to the allowable budget to determine if the system complies.

The fan system is a multi-zone VAV fan type, with an airflow greater than 10,000 cfm. Therefore, W/cfm values from the third column from the left from Tables 140.4-A and 140.4-B are used. The applicable supply side allowance (taken from Table 140.4-A) for this system type (i.e., a multi-zone VAV system greater than 10,000 cfm) are summarized in the table below.

Name of Credit	W/cfm
Supply System Base Allowance	0.413
MERV 13 to MERV 16 Filter (two times the clean filter pressure drop)	0.105
Gas heat	0.070
Hydronic/DX cooling coil, or heat pump coil (wet) [Healthcare facilities can select twice]	0.105
Economizer return damper	0.035
Deduction for systems that feed a terminal unit with a fan with electrical input power < 1kW	-0.100*

*This value must be adjusted to reflect airflow passing through the VAV boxes

The following formula is used to adjust the terminal unit deduction.

$$FPA_{adj} = \frac{Q_{comp}}{Q_{sys}} X\, FPA_{comp}$$

The adjusted fan power allowance for each parallel fan powered VAV box is show below.

Series FPAadj = (2* 600 / 12,000) x (-0.100) = -0.010

Taking this adjustment into account, the total supply side power allowance is 0.718 W/cfm, and at 12,000 cfm, this is 8.62 kW.

The return fan system only qualifies for the base allowance, which is 0.236 W/cfm. At 11,000 cfm, this is 2.60 kW.

The supply and return fan systems are evaluated separately since the return fan is not in the same cabinet as the supply fan.

The actual supply-only fan system total electrical power input is 7.35 kW, so this fan system complies with Section 140.4(c). The proposed return fan system exceeds the allowance of 2.60 kW, so does not comply.

Example 4-46

Question

A conventional VAV system serves an office building. Fan performance is as described in the table below. Is the system in compliance with Section 140.4(c)?

Quantity	Fan Service	Design cfm, each	bhp	Nameplate Motor hp	Input kW per AMCA 207
2	Supply fans with variable-speed drives	75,000	70.5	75	56.78
4	Economizer relief fans	32,000	3.5	5	2.9
1	Toilet exhaust	6,750	2.7	3	2.32
1	Elevator machine room exhaust fan	5,000	Unknown	3/4	n/a
2	Cooling tower exhaust fans	Unknown	Unknown	15	n/a
15	Conference room exhaust fans	500	0.21	1/4	0.24
120	Series-type fan-powered mixing boxes	1,250 (average)	Unknown	1/3	n/a

Answer

First, determine which fans to include in the fan power calculation:

- Supply fans are included.
- The economizer relief fans are not included because they will not operate at peak cooling design conditions. Had return fans been used, they would have to be included in the calculation.

• The toilet exhaust fan is included because it exhausts conditioned air from the building rather than have it returned to the supply fan, and it operates at peak cooling conditions.

• The elevator exhaust fan is not part of the system because it is assumed, assumed that the fan consumes less than 1 kW of input electrical power (even though the bhp is not available, the maximum electrical input power for fans with a motor hp < 1 is 0.89 from Table 140.4-D). • The cooling tower fans operate at design conditions, but they also are not part of the system because they circulate only outdoor air. Although the cooling tower fan power does not contribute to the system fan power, it is required to meet the minimum efficiency requirements in Table 110.2-G.

• The conference room exhaust and series-type fan-powered VAV boxes are not included because they consume less than 1 kW each. However, the terminal unit deduction will be applied for the VAV boxes, as explained below.

Second, calculate the allowable fan power budget. The applicable allowances are shown in the table below. The system is assumed to be a single cabinet fan system. The allowances are from the >10,000 cfm multi-zone VAV column of Table 140.4-A and 140.4-B.

Name of Credit	W/cfm
Supply System Base Allowance	0.413
MERV 13 to MERV 16 Filter (mid-life)	0.105
Gas heat	0.070
Hydronic/DX cooling coil, or heat pump coil (wet) [Healthcare facilities can select twice]	0.105
Economizer return damper	0.035
Deduction for systems that feed a terminal unit with a fan with electrical input power < 1kW	-0.100*
Exhaust System Base Allowance	0.236

The exhaust system base allowance is included since this is being treated as a single cabinet fan system.

In order to calculate the appropriate deduction for the fan-powered VAV boxes, the following procedure is to be followed.

$$FPA_{adj} = \frac{Q_{comp}}{Q_{sys}} X \, FPA_{comp}$$

The adjusted fan power allowance for each parallel fan powered VAV box is show below.

FPAadj = (1,250 / 150,000) x (-0.100) = -0.0008333

Given that there are 120 fan powered VAV boxes, the total deduction is calculated below.

Terminal unit FPAadj = 120 x FPAadj = -0.100 W/cfm

Note that this is the same value as the initial deduction since all of the supply airflow passes through the 120 VAV boxes.

The allowances add up to 0.864 W/cfm, which, when multiplied by 150,000 cfm yields 129.60 kW.

The bathroom exhaust fan is also in-scope, and its allowance is calculated using the exhaust system base allowance (0.236 W/cfm) multiplied by the airflow (6,750 cfm), which yields 1.59 kW.

The total power allowance is 131.19 kW. The actual input power of the in-scope fans is 115.88 kW (this includes the two supply fans and the toilet exhaust fan), so this system meets the requirements of Section 140.4(c). If the system did not comply, the designer could consider using larger ducts to reduce static pressure.

Example 4-47

Question

A hotel/motel building has floor-by-floor supply air-handling units but central toilet exhaust fans and minimum ventilation supply fans. How is the standard applied to this system?

Answer

Each air handler is as a single-cabinet fan system, the central ventilation fan is a supply-only system, and the central exhaust is an exhaust system. Each fan system is evaluated separately.

Example 4-48

Question

A wing of an elementary school building is served by eight water-source heat pumps, each equipped with a 3/4 hp fan motor and serving a single classroom. Ventilation air is supplied directly to each classroom by a dedicated outdoor-air system. Each classroom requires 500 cfm of outdoor air, so the system delivers the total of 4000 cfm of conditioned outdoor air using a 5 hp fan. Does this system need to comply with Section 140.4(c)?

Answer

The water-source heat pumps are not counted since their motors consume less than 1 kW. The dedicated outdoor-air system fan, which consumes more than 1 kW, is evaluated on its own. If the outdoor air is passes through the fans of the water-source heat pumps, the 0.100 w/cfm deduction in Table 140.4-A would be applied.

Example 4-49

Question

A variable-volume air handler serving a lab system at 4,400 feet altitude has a fan system design supply airflow of 10,000 cfm. The supply fan has a 15 hp (nameplate) supply fan motor that operates at an input power of 10.7 bhp. The return fan is in the same cabinet as the supply fan and has a three hp motor that operates at an input power of 2.5 bhp. The system has hydronic heating and cooling coils. Flow control devices in the exhaust are used to maintain pressure relationships between spaces served by the system.

The air handler uses MERV 13 filters and exhaust air is completely ducted. The system uses outdoor air and has a run-around heat recovery system with coils in the supply and exhaust airstreams, each with 0.4 in. of water pressure drop at design airflow.

Does this fan system comply with the fan power requirements in Section 140.4(c)?

Answer

This system is treated as a single-cabinet fan system. The correct column from which to select allowances is "multi-zone VAV systems >5,000 and ≤10,000 cfm." The altitude correction factor will need to be applied to the fan power allowance once all allowances are summed up. The allowable allowances for the supply and return sides are shown in the tables below.

Supply Side Credits	W/cfm
Supply System Base Allowance	0.453
MERV 13 to MERV 16 Filter (two times the clean filter pressure drop)	0.114
Hydronic heating coil (central)	0.048
Hydronic/DX cooling coil, or heat pump coil (wet) [Healthcare facilities can select twice]	0.114
Coil Runaround Loop	0.114
Economizer return damper	0.038
Supply Side Total	0.881

Return Side Credits	W/cfm
Exhaust System Base Allowance	0.246
Return or exhaust systems required by code or accreditation standards to be fully ducted, or systems required to maintain air pressure differentials between adjacent rooms	0.100
Return and/or exhaust airflow control devices	0.100
Return Side Total	0.446

The grand total for all allowances is 0.881 + 0.446 = 1.327 W/cfm, however, this value must be multiplied by the altitude correction factor to account for reduced air density, found in Table 140.4-C. Since the building is at 4,400 ft elevation, the applicable factor is 0.864. The resulting corrected power allowance is 1.327 W/cfm x 0.864 = 1.147 W/cfm.

The final step is to multiply the power allowance rate by the system airflow, as shown below.

Allowable power = 1.147 W/cfm x 10,000 cfm / 1,000 W/kW = 11.47 kW.

The fan electrical input power can be calculated using the provided fan brake horsepower values along with AMCA 207 to estimate transmission, motor, and motor controller losses. Assuming both motors are direct drive, have a motor controller, are ODP, and are 4-pole motors, the supply fan input power is 8.89 kW, and the return fan input power is 2.29 kW, for a total of 11.18 kW. Therefore, this system meets the requirements of Section 140.4(c).

Exhaust airstream has a MERV 8 filter. The system requires 0.50" w.c. of external static pressure and consumes 2.85 kW at design conditions, as provided by the manufacturer. Does the system comply with Section 140.4(c)?

Answer

Since this system does not meet the definition of "multi zone VAV", the allowance will be selected from the "all other systems ≤ 5,000 cfm" column. The system will be treated as a single cabinet fan system. The applicable allowance is displayed in the table below.

Table Source	Name of Credit	W/cfm
140.4-A	Supply System Base Allowance	0.232
140.4-A	MERV 13 to MERV 16 Filter (two times the clean filter pressure drop)	0.139
140.4-A	100% Outdoor air system meeting the requirements of Note 2.	0.070
140.4-A	Enthalpy Recovery Ratio (ERR ≥ 0.8)	0.289
140.4-B	Exhaust System Base Allowance	0.186
140.4-B	Filter (any MERV value)	0.046
140.4-B	Enthalpy Recovery Ratio (ERR ≥ 0.8)	0.291
Total Allowance		1.254

For a 3,000 cfm system, this results in an allowable power of (1.254 W/cfm) x (3,000 cfm) / (1,000 W/kW) = 3.76 kW. Since the system power consumption is 2.85 kW, this system meets the requirements of Section 140.4(c).

4.7.2.6 Fractional HVAC Motors for Fans

§140.4(c)4 and §170.2(c)Aiii

HVAC fan motors that are one hp or less and 1/12 hp or greater shall be electronically commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with the National Electric Manufacturers Association (NEMA) Standard MG 1-2006 at full-load rating conditions. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

This requirement can be met with either electronically commutated motors or brushless direct current (DC) motors. These motors have higher efficiency than permanent split capacitor (PSC) motors and inherently have speed control that can be used for VAV operation or balancing.

This requirement includes fan-powered terminal units, fan-coil units, exhaust fans, transfer fans, and supply fans. There are three exceptions to this requirement:

1. Motors in fan-coil units and terminal units that operate only when providing heating to the space served. This includes parallel style fan-powered VAV boxes and heating only fan-coils.
2. Motors that are part of space conditioning equipment certified under §110.1 or §110.2. This includes supply fans, condenser fans, ventilation fans for boilers, and other fans that are part of equipment that is rated as a whole.
3. Motors that are part of space conditioning serving healthcare facilities.

4.7.2.7 Electric-Resistance Heating

§140.4(g), §141.0, and §170.2(c)4E

The Energy Code strongly discourage the use of electric-resistance space heat. Electric-resistance space heat is not allowed in the prescriptive approach except where:

1. Site-recovered or site-solar energy provides at least 60 percent of the annual heating energy requirements.
2. A heat pump is supplemented by an electric-resistance heating system, and the heating capacity of the heat pump is more than 75 percent of the design heating load at the design outdoor temperature (determined in accordance with the Energy Code).
3. The total capacity of all electric-resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building.
4. The total capacity of all electric-resistance heating systems serving the building, excluding those that supplement a heat pump, is no more than 3 kW.
5. An electric-resistance heating system serves an entire building that:
   a. Is not a hotel/motel building.
   b. Has a conditioned floor area no greater than 5,000 sq ft.
   c. Has no mechanical cooling.
   d. Is in an area where natural gas is not currently available and an extension of a natural gas system is impractical, as determined by the natural gas utility.

6. The existing mechanical systems use electric reheat (when adding VAV boxes) added capacity cannot exceed 20 percent of the existing installed electric capacity, under any one permit application in an alteration.
7. The existing VAV system with electric reheat is being expanded, the added capacity cannot exceed 50 percent of the existing installed electric reheat capacity under any one permit in an addition.
8. Heating systems serve as emergency backup to gas heating equipment.

The Energy Code allow a small amount of electric-resistance heat to be used for local space heating or reheating (provided reheat is in accordance with these regulations).

Example 4-50

Question

If a heat pump is used to condition a building having a design heating load of 100,000 Btu/h at 35 degrees F, what are the sizing requirements for the compressor and heating coils?

Answer

The compressor must be sized to provide at least 75 percent of the heating load at the design heating conditions, or 75,000 Btu/h at 35 degrees F. The Energy Code do not address the size of the resistance heating coils. Normally, they will be sized based on heating requirements during defrost.

4.7.2.8 Cooling Tower Flow Turndown

§140.4(h)3 and §170.2(c)4Fii

The Energy Code requires that open cooling towers with multiple condenser water pumps be designed so that all cells can be run in parallel with the larger of the flow that is produced by the smallest pump or 50 percent of the design flow for the cell.

In a large plant at low load operation, not all the cells are typically run at once. This is allowed in the Energy Code.

Cooling towers are very efficient at unloading the fan energy drops off as the cube of the airflow. It is always more efficient to run the water through as many cells as possible- two fans at half speed use less than one third of the energy of one fan at full speed for the same load. Unfortunately, there is a limitation with flow on towers. The flow must be sufficient to provide full coverage of the fill. If the nozzles do not fully wet the fill, air will go through the dry spots providing no cooling benefit and cause the water at the edge of the dry spot to flash evaporate, depositing dissolved solids on the fill.

Fortunately, the cooling tower manufacturers do offer low-flow nozzles (and weirs on basin type towers) to provide better flow turndown. This typically only costs

$100 to $150 per tower cell. As low-flow nozzles can eliminate the need for a tower isolation control point, this option provides energy savings at a reduced first cost.

Example 4-51

Question

If a large central plant has five equally sized chillers and five equally sized cooling tower cells do all of the cooling tower cells need to operate when only one chiller is on-line?

Answer

No. You would probably only run three cells with one chiller. The cooling tower cells must be designed to run at 33 percent of their nominal design flow. With two to five chillers running, you would run all of the cells of the cooling tower. With only one chiller running you would run three cells. In each case, you would need to keep the tower flow above the minimum that it was designed for.

4.7.2.9 Centrifugal Fan Limitation

§140.4(h)4 and §170.2(c)4Fiii

Open cooling towers with a combined rated capacity of 900 gpm and greater are prohibited from using centrifugal fans. The 95-degree F condenser water return, 85-degree F condenser water supply and 75-degree F outdoor wet-bulb temperature are test conditions for determining the rated flow capacity in gpm. Centrifugal fans use approximately twice the energy as propeller fans for the same duty. There are a couple of exceptions to this requirement:

1. Cooling towers that are ducted (inlet or discharge) or have an external sound trap that requires external static pressure capability.
2. Cooling towers that meet the energy efficiency requirement for propeller fan towers in Table 4-7.

Centrifugal fans may be used on closed circuit fluid coolers.

As with all prescriptive requirements centrifugal fan cooling towers may be used when complying with the performance method. The budget building will be modeled using propeller towers.

4.7.2.10 Cooling Tower Efficiency

§140.4(h)5 and §170.2(c)4Fv

Prescriptively, axial fan open-circuit cooling towers with a combined rated capacity of 900 gpm or greater must achieve a rated efficiency no less than 60 gpm/hp. This efficiency is rated at specific temperature conditions which are 95-degree F condenser water return; 85-degree F condenser water supply; and 75-degree F outdoor wet-bulb temperature as listed in Table 4-7. There are a couple of exceptions to this requirement:

1. Cooling towers that are installed as a replacement to an existing chilled water plant if the tower is located on an existing roof or inside an existing building.
2. Cooling towers that are serving buildings in Climate Zones 1 or 16.

As with all prescriptive requirements, axial-fan open-circuit cooling towers with a capacity of 900 gpm or larger and less than 60 gpm/hp may be used when complying with the performance method. The towers must still comply with the mandatory minimum efficiency rating of 42.1 gpm/hp as listed in Table 4-7.

4.7.2.11 Chiller Efficiency

§140.4(i) and §170.2(c)4G

In Table 4-4, there are two sets of efficiency for almost every size and type of chiller. Path A represents fixed speed compressors and Path B represents variable speed compressors. For each path, there are two efficiency requirements: a full load efficiency and an integrated part-load efficiency. Path A typically has a higher full load efficiency and a lower part-load efficiency than Path B. In all California climates, the cooling load varies enough to justify the added cost for a Path B chiller. This is a prescriptive requirement, so Path B is used in the base case model in the performance method.

There are a number of exceptions provided to this requirement:

1. Chillers with an electrical service of greater than 600 volts. This is due to the fact that the cost of a VSD is much higher on medium voltage service.
2. Chillers attached to a heat recovery system with a design heat recovery capacity greater than 40 percent of the chiller's design cooling capacity. Heat recovery typically requires operation at higher lifts and compressor speeds.
3. Chillers used to charge thermal energy storage systems with a charging temperature of less than 40 degrees F. This again requires a high lift operation for chillers.
4. In a building with more than three chillers only three are required to meet the Path B efficiencies.

4.7.2.12 Limitation on Air Cooled Chillers

§140.4(j),§141.0, and §170.2(c)4G

New central cooling plants and cooling plant expansions will be limited on the use of air-cooled chillers. For both types the limit is 300 tons per plant.

In the studies provided to support this requirement, air cooled chillers always provided a higher life cycle cost than water-cooled chillers even accounting for the water and chemical treatment costs.

Exceptions to this requirement:

1. Where the water quality at the building site fails to meet manufacturer's specifications for the use of water-cooled chillers.

   This exception recognizes that some parts of the state have exceptionally high quantities of dissolved solids that could foul systems or cause excessive chemical treatment or blow down.

2. Chillers that are used to charge a thermal energy storage system with a design temperature of less than 40 degrees F.

   This addresses the fact that air-cooled chillers can operate very efficiently at low ambient air temperatures. Since thermal energy storage systems operate for long hours at night, these systems may be as efficient as a water-cooled plant. The chiller must be provided with head pressure controls to achieve these savings.

3. Air cooled chillers with minimum efficiencies approved by the Energy Commission pursuant to §10-109(d).

   This exception was provided in the event that an exceptionally high efficiency air cooled chiller was developed. None of the high-efficiency air-cooled chillers currently evaluated are as efficient as water-cooled systems using the lowest chiller efficiency allowed by §110.2.

4. Systems serving healthcare facilities.

4.7.2.13 Exhaust System Transfer Air

§140.4(o) and §170.2(c)4M

The standard prescriptively requires the use of transfer air for exhaust air makeup in most cases. The purpose is to avoid supply air that requires increased outdoor air intake, which would require conditioning, for exhaust makeup when return or relief air from neighboring spaces can be used instead. The requirement limits the supply of conditioned air to not exceed the larger of 1.) the supply flow required for space heating or space cooling, 2.) the required ventilation rate, or 3.) the exhaust flow, minus the available transfer air from conditioned spaces or plenums on the same floor and within 15 ft and not in different smoke or fire compartments. Available transfer air does not include air required to maintain pressurization and air that cannot be transferred based on-air class as defined by in §120.1.

There are a few exceptions to this requirement:

1. Biosafety laboratories classified Level 3 or higher
2. Vivarium spaces
3. Spaces that are required by applicable codes and standards to be maintained at positive pressure relative to adjacent spaces. For spaces taking this exception, any transferable air that is not directly transferred shall be made

available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.

4. Spaces where the demand for transfer air may exceed the available transfer airflow rate and where the spaces have a required negative pressure relationship. For spaces taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.

5. Healthcare facilities

A compliant example would be a space with a restroom with 300 cfm of exhaust. The makeup air would consist of 60 cfm of supply air and 240 cfm of transfer air from an adjacent ceiling return air plenum. The amount of air required for the space is 60 cfm for heating and cooling and the rest of the makeup air is transferred from the return air plenum.

A non-compliant example would be if the same space had a constant air volume box with reheat supplying all of the makeup air. The reheat would be needed to prevent the space from being overcooled. Since there is transfer air available in the adjacent plenum, the maximum allowed supply air would be only what's required for space heating or cooling, which would be 60 cfm.

4.7.2.13.1.1 Dedicated Outdoor Air Systems (DOAS)

§140.4(p)

Systems specifying DOAS units must comply with the following requirements to ensure a compliant system:

1. DOAS fan efficiency: If the DOAS unit fan power is less than 1 kW, then the fan efficiency of that fan must be less than or equal to 1.0 watt per cubic foot per minute. If the fan power is greater than or equal to 1 kW, it is subject to the fan power budgets requirements under Section 140.4(c).
2. Reducing terminal unit fan power: in order to ensure that adequate ventilation air can be provided to the space without severely impacting the ability of independent terminal unit fans to shut off when not needed, the following scenarios are compliant:
   A. Ventilation air provided by the DOAS unit must be provided directly to the space
   B. Ventilation air is provided to the outlet of the terminal heating or cooling coils (such as a VRF).
   C. A system using active-chilled beam systems
   D. Sensible-only cooling terminal units with pressure independent variable airflow devices that limit DOAS supply air to the greater of latent load or minimum ventilation requirements.
   E. Any configuration where the downstream terminal fans use no greater

than 0.12 watts per cubic foot per minute.

3. Airflow Balance: supply and exhaust fans for the DOAS shall have a minimum of three speeds for system balancing
4. Limiting reheat: if a DOAS utilizes mechanical cooling, then the DOAS ventilation air shall not use supply air above 60°F when the majority of zones require cooling.

Note: under certain climate zones and air handler design scenarios, DOAS units may also require Exhaust Air Heat Recovery requirements under section 140.4(q).

4.7.2.13.1.2 Exhaust Air Heat Recovery (EAHR)

§140.4(q)

HVAC systems (including DOAS) must comply with EAHR requirements if their air handling systems meet design specifications that trigger compliance. For most HVAC systems these requirements are triggered if the full design airflow meets the criteria in Table 4- for air handlers designed to operate continuously or Table 4- for all other air handlers.

These requirements are also triggered if a decoupled DOAS system is utilizing Exhaust Air Heat Recovery instead of meeting economizer requirements for the independent space-conditioning indoor units using the DOAS-Economizer exception (EXCEPTION 6 to 140.4(e)).

1. The HVAC System must utilize an exhaust air heat recovery device with an energy recovery ratio of 60 percent or an enthalpy recovery ratio of 50 percent for both heating and cooling (note: climate zone 1 only needs to comply with heating requirements and climate zone 15 only needs to comply with heating requirements).

2. The HVAC System must utilize energy recovery or bypass controls to disable exhaust air heat recovery and directly economizer with ventilation air.

Exceptions to §140.4(q)1

1. Laboratory and factory exhaust systems (those meeting Section 140.9c)
2. Systems designed to condition to 60 degrees or less
3. Systems within heating-dominated Climate Zone 16 (only) where 60% of heating energy is recovered on site.
4. Systems where the usable[2] exhaust air is too distributed to utilize for heat recovery (systems where a quantity of less than 75 percent of the outdoor airflow rate can be gathered within 20 linear feet).

[2] (1) Unusable exhaust air includes air used for another energy recovery system; (2) air not allowed for energy recovery under the CMC; (3) Class 4 air as specified under Section 120.1(g)

5. Systems with low operating hours (20 hours or less per week)

Example 4-50

Question

If a building has some areas that need continuous operation (24 hours per day & 7 days a week) and some which has lower hours, which table of Exhaust Air Heat Recovery requirements do you need to follow?

Answer

These requirements are system-based and **not** building-based. If any part of an air handling system serves an area that need to operate 24/7, they will need to comply with the requirements under the greater than 8,000 hours per year table or else take a relevant exception.

Table 4-11: Airflow threshold (CFM) requiring energy recovery by climate zone and percent outdoor air at full design airflow (less than 8,000 hours per year)

% Outdoor Air at Full Design Airflow	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
≥10% and <20%	NR	NR	NR	NR	NR	NR	NR	NR
≥20% and <30%	≥15,000	≥20,000	NR	NR	NR	NR	NR	NR
≥30% and <40%	≥13,000	≥15,000	NR	NR	NR	NR	NR	NR
≥40% and <50%	≥10,000	≥12,000	NR	NR	NR	NR	NR	NR
≥50% and <60%	≥9,000	≥10,000	NR	≥18,500	NR	NR	NR	NR
≥60% and <70%	≥7,000	≥7,500	NR	≥16,500	NR	NR	NR	NR
≥70% and <80%	≥6,500	≥7,000	NR	≥15,000	NR	NR	NR	NR
≥80%	≥4,500	≥6,500	NR	≥14,000	NR	NR	NR	NR
% Outdoor Air at Full Design Airflow	**CZ 9**	**CZ 10**	**CZ 11**	**CZ 12**	**CZ 13**	**CZ 14**	**CZ 15**	**CZ 16**
≥10% and <20%	NR	NR	NR	NR	NR	NR	NR	NR
≥20% and <30%	NR	NR	≥18,500	≥18,500	≥18,500	≥18,500	≥18,500	≥18,500

≥30% and <40%	NR	NR	≥15,000	≥15,000	≥15,000	≥15,000	≥15,000	≥15,000
≥40% and <50%	NR	≥22,000	≥10,000	≥10,000	≥10,000	≥10,000	≥10,000	≥10,000
≥50% and <60%	NR	≥17,000	≥8,000	≥8,000	≥8,000	≥8,000	≥8,000	≥8,000
≥60% and <70%	≥20,000	≥15,000	≥7,000	≥7,000	≥7,000	≥7,000	≥7,000	≥7,000
≥70% and <80%	≥17,000	≥14,000	≥5,000	≥5,000	≥5,000	≥5,000	≥5,000	≥5,000
≥80%	≥15,000	≥13,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000

Table 4-12a: Airflow threshold (CFM) requiring energy recovery by climate zones and percent outdoor air at full design airflow (greater than 8,000 hours per year)

% Outdoor Air at Full Design Airflow	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
≥10% and <20%	≥10,000	≥10,000	NR	NR	NR	NR	NR	NR
≥20% and <30%	≥2,000	≥5,000	≥13,000	≥9,000	≥9,000	NR	NR	NR
≥30% and <40%	≥2,000	≥3,000	≥10,000	≥6,500	≥6,500	NR	NR	NR
≥40% and <50%	≥2,000	≥2,000	≥8,000	≥6,000	≥6,000	NR	NR	NR
≥50% and <60%	≥2,000	≥2,000	≥7,000	≥6,000	≥6,000	NR	NR	≥20,000
≥60% and <70%	≥2,000	≥2,000	≥6,000	≥6,000	≥6,000	NR	NR	≥18,000
≥70% and <80%	≥2,000	≥2,000	≥6,000	≥5,000	≥5,000	NR	NR	≥15,000
% Outdoor Air at Full Design Airflow	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
≥10% and <20%	NR	≥40,000	≥40,000	≥20,000	≥10,000	≥10,000	≥10,000	≥10,000
≥20% and <30%	NR	≥15,000	≥15,000	≥5,000	≥5,000	≥5,000	≥5,000	≥5,000
≥30% and <40%	≥15,000	≥7,500	≥7,500	≥3,000	≥3,000	≥3,000	≥3,000	≥3,000
≥40% and <50%	≥12,000	≥6,000	≥6,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000
≥50% and <60%	≥10,000	≥5,000	≥5,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000
≥60% and <70%	≥9,000	≥4,000	≥4,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000
≥70% and <80%	≥8,000	≥3,000	≥3,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000
≥80%	≥7,000	≥3,000	≥3,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000

4.8 Water Heating Requirements

Service water heating requirements applicable to nonresidential occupancies are mandatory measures; non-school buildings must also meet prescriptive high-capacity water heating system requirements. Multifamily buildings, hotels, and motels, must also comply with the Energy Code§160.4 and §170.2(d), described below.

There are no acceptance requirements for water heating systems or equipment. However, central water heating systems serving multifamily, hotel and motel buildings must meet the distribution system eligibility criteria for that portion of the system that is applicable.

4.8.1 Service Water Systems Mandatory Requirements

4.8.1.1 Efficiency and Control

§110.3(a)&(b)

Any service water heating equipment must meet all efficiency requirements under the Appliance Efficiency Regulations (Title 20) and have integral automatic temperature controls that allow the temperature to be adjusted from the lowest to the highest allowed temperature settings for the intended use as listed in Table 3, Chapter 50 of the ASHRAE Handbook, HVAC Applications Volume.

Service water heaters installed in residential occupancies need not meet the temperature control requirement of §110.3(a)1.

4.8.1.2 Multiple Temperature Usage

§110.3(c)1

For systems with a total capacity greater than 167,000 Btu/h, outlets requiring higher than service water temperatures (as listed in the ASHRAE Handbook, HVAC Applications Volume) shall have separate remote heaters, heat exchangers, or boosters to supply the outlet with the higher temperature. This requires the primary water heating system to supply water at the lowest temperature required by any of the demands served for service water heating. All other demands requiring higher temperatures should be served by separate systems, or by boosters that raise the temperature of the primary supply.

Systems serving healthcare facilities and clinics, which are covered by California Plumbing Code Section 613.0, shall instead follow the requirements of that section.

4.8.1.3 Controls for Hot Water Distribution Systems

§110.3(c)2

Service hot water systems with a circulating pump or with electrical heat trace shall include a control capable of automatically turning off the system when hot water is not required. Such controls include automatic time switches, interlocks with HVAC time switches, occupancy sensors, and other controls that accomplish the intended purpose.

Systems serving healthcare systems are exempted from this requirement.

4.8.1.4 Storage Tank Insulation

§110.3(c)3

Unfired water heater storage tanks and backup tanks for solar water heating systems must have one of the following:

1. External insulation with an installed R-value of at least R-3.5.
2. Internal and external insulation with a combined R-value of at least R-16.
3. The heat loss of the tank based on an 80-degree F water-air temperature difference shall be less than 6.5 Btu per hour per sq ft. This corresponds to an effective resistance of R-12.3.

4.8.1.5 Systems with Recirculation Loops; Systems Serving Multiple Dwelling Units

§110.3(c)4; 160.4(b)

Service water systems with central recirculation distribution must include all of the following mandatory features. The intent of these measures is to optimize performance and allow for lower cost of maintenance. These requirements are applicable to nonresidential occupancies as well as multifamily and hotel/motel systems.

G. Air Release Valves

§110.3(c)4A

The constant supply of new water and leaks in system piping or components during normal operation of the pump may introduce air into the circulating water. Entrained air in the water may also contribute to increased cavitation, the formation of vapor bubbles in liquid on the low pressure (suction) side of the pump. The vapor bubbles generally condense back to the liquid state after they pass into the higher-pressure side of the pump. Cavitation contributes to a loss of head pressure and pumping capacity, may produce noise and vibration in the pump, and may result in pump impeller corrosion, all of which impacts the pumps' efficiency and life expectancy.

Entrained air and cavitation should be minimized by the installation of an air release valve. The air release valve must be located no more than 4 feet from the inlet of the pump, and must be mounted on a vertical riser with a length of at least 12 inches. Alternatively, the pump shall be mounted on a vertical section of the return piping.

H. Recirculation Loop Backflow Prevention

§110.3(c)4B

Temperature and pressure differences in the water throughout a recirculation system can create potentials for backflows, resulting in cooler water from the bottom of the water heater tank and water near the end of the recirculation loop flowing backwards towards the hot water load and reducing the delivered water temperature.

To prevent this from occurring, the Energy Code requires that a check valve or similar device be located between the recirculation pump and the water heating equipment.

I. Equipment for Pump Priming/Pump Isolation Valves

§110.3(c)5C&D

Many systems are allowed to operate to complete failure due to the difficulty of repair or servicing. Repair labor costs can be reduced significantly by planning ahead and designing for easy pump replacement. Provisions for pump priming and pump isolation valves help reduces maintenance costs.

To meet the pump priming equipment requirement, a hose bibb must be installed between the pump and the water heater. In addition, an isolation valve shall be installed between the hose bibb and the water heating equipment. This configuration will allow the flow from the water heater to be shut off, allowing the hose bibb to be used for bleeding air out of the pump after replacement.

The requirement for the pump isolation valves will allow replacement of the pump without draining a large portion of the system. The isolation valves shall be installed on both sides of the pump. These valves may be part of the flange that attaches the pump to the pipe. One of the isolation valves may be the same isolation valve as in §110.3(c)5C.

J. Connection of Recirculation Lines

§110.3(c)4E

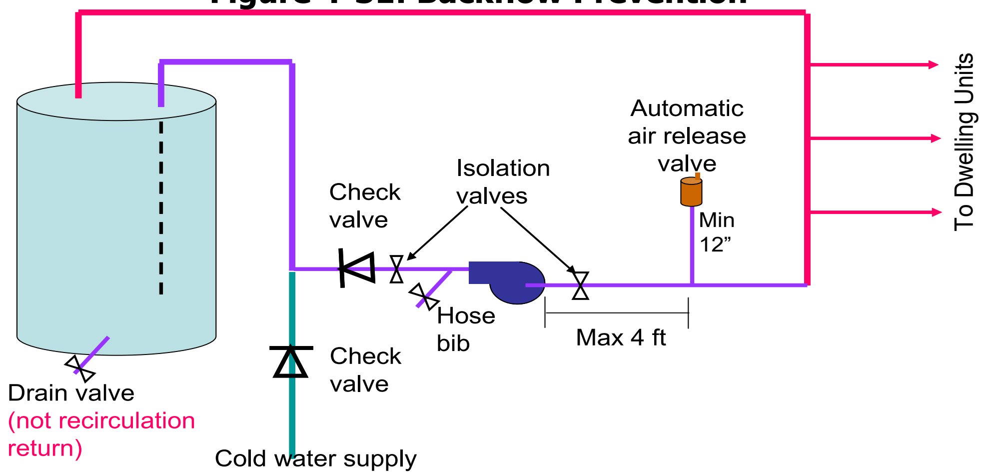
Manufacturer specifications should always be followed to assure optimal system performance. The cold-water piping and the recirculation loop piping should never be connected to the hot water storage tank drain port.

K. Backflow Prevention in Cold Water Supply

§110.3(c)4F

The dynamic between the water in the heater and the cold-water supply are similar to those in the recirculation loop. Thermosyphoning can occur on this side of the loop just as it does on the recirculation side of the system. To prevent this, the Energy Code requires a check valve to be installed on the cold-water supply line. The valve should be located between the hot water system and the next closest tee on the cold-water supply line. The system shall comply with the expansion tank requirements of California Plumbing Code, §608.3.

Figure 4-31: Backflow Prevention



4.8.1.6 Service Water Heaters in State Buildings

§110.3(c)5

Newly constructed buildings constructed by the State of California shall have water heating systems designed to derive at least 60 percent of the energy needed for service water heating from site solar energy or recovered energy. There is an exception for buildings where site solar or recovered energy service water heating is economically or physical infeasible, as determined by the state architect. See the Compliance Options section below for more information about solar water heating systems.

4.8.1.7 Isolation Valves for Instantaneous Water Heaters

§110.3(c)6, 160.4(d)

All newly installed instantaneous water heaters with an input greater than 6.8 kBtu/h or 2 kW shall have isolation valves on both the incoming cold water supply and the hot water pipe leaving the water heater, to assist in the flushing of the heat exchanger and help prolong the life the water heaters. Instantaneous water heaters with integrated drain ports for servicing are acceptable to meet the requirement and will not require additional isolation valves.

4.8.1.8 Pipe Insulation

§120.3

All requirements of §120.3 also apply to service water heating in nonresidential, hotel and motel buildings. See Section 4.5.1.1 for full details

For pipes with conductivity ranges within those specified in Table 4-23, the nominal pipe diameters grouping ranges have changed, as well as the thickness of insulation required for each pipe diameter range. The table is repeated below for ease of reference:

Table 4-23: Pipe Insulation

<table>
<tr><th rowspan="3">FLUID TEMPERATURE RANGE (°F)</th><th rowspan="3">CONDUCTIVITY RANGE (in Btu-inch per hour per sq ft per °F)</th><th rowspan="3">INSULATION MEAN RATING TEMPERATURE (°F)</th><th colspan="7">NOMINAL PIPE DIAMETER (in inches)</th></tr>
<tr><th colspan="2">1 and less</th><th colspan="2">1 to <1.5</th><th>1.5 to < 4</th><th>4 to < 8</th><th>8 and larger</th></tr>
<tr><th colspan="7">INSULATION THICKNESS REQUIRED (in inches)</th></tr>
<tr><td colspan="10">Space heating, hot water systems (steam, steam condensate and hot water) and service water heating systems (recirculating sections, all piping in electric trace tape systems, and the first eight ft of piping from the storage tank for nonrecirculating systems)</td></tr>
<tr><td>Above 350</td><td>0.32-0.34</td><td>250</td><td colspan="2">4.5</td><td colspan="2">5.0</td><td>5.0</td><td>5.0</td><td>5.0</td></tr>
<tr><td>251-350</td><td>0.29-0.31</td><td>200</td><td colspan="2">3.0</td><td colspan="2">4.0</td><td>4.5</td><td>4.5</td><td>4.5</td></tr>
<tr><td>201-250</td><td>0.27-0.30</td><td>150</td><td colspan="2">2.5</td><td colspan="2">2.5</td><td>2.5</td><td>3.0</td><td>3.0</td></tr>
<tr><td>141-200</td><td>0.25-0.29</td><td>125</td><td colspan="2">1.5</td><td colspan="2">1.5</td><td>2.0</td><td>2.0</td><td>2.0</td></tr>
<tr><td>105-140</td><td>0.22-0.28</td><td>100</td><td colspan="2">1.0</td><td colspan="2">1.5</td><td>1.5</td><td>1.5</td><td>1.5</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td colspan="10">Space cooling systems (chilled water, refrigerant and brine)</td></tr>
<tr><td colspan="3"></td><td>Nonres</td><td>Res</td><td>Nonres</td><td>Res</td><td colspan="3"></td></tr>
<tr><td>40-60</td><td>0.21-0.27</td><td>75</td><td>0.5</td><td>0.75</td><td>0.5</td><td>0.75</td><td>1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Below 40</td><td>0.20-0.26</td><td>50</td><td colspan="2">1.0</td><td colspan="2">1.5</td><td>1.5</td><td>1.5</td><td>1.5</td></tr>
</table>

Source: California Energy Commission, Building Energy Efficiency Standards, Table 120.3-A

4.8.2 Mandatory Requirements Applicable to Multifamily and Hotel/Motel

In addition to the mandatory requirements listed above, there are mandatory requirements that will apply to water heating systems for hotels, motels, and multifamily buildings only. All of these requirements are tied to the mandatory requirements in §160.4 for multifamily occupancies. The applicability of the mandatory features listed above will change depending on whether the water heating system has a central system or uses individual water heaters.

4.8.2.1 Individual Dwelling Units

§160.4(a)

Systems using gas or propane water heaters to serve individual dwelling units must include:

1. An unobstructed, dedicated 125V 20A receptacle connected to the electrical panel via a 120/240V 3-conductor 10-gauge copper branch circuit, which is no further than 3 ft. from the water heater. The unused conductor ends must be electrically isolated and labeled “spare”, and a single-pole breaker space must be reserved next to the breaker for the branch circuit

2. Either a Category III/IV vent, or a Type B vent with straight pipe between the outside end and the water heater location. Higher output water heaters often require different vent materials due to the presence of acidic condensation from flue gases. The standard Type B vent installed for conventional atmospheric gas water heaters is made of steel and would soon be destroyed by the condensate. Thus, the Energy Code only allows Type B vents for water heaters when there is a straight shot between the water heater and where the vent leaves the building, with no bends along the path of the Type B vent, except the portion of the vent outside the building, and in the space where the water heater is installed. The installation shall meet all code and manufacturers' guidelines. Because Category III and IV pipes are usually smaller than those for Type B vents, a straight Type B vent can be easily modified into a Category III or IV vent by simply inserting a new vent pipe through the existing Type B vent pipe. A flue pipe that makes bends though the building structure is not easy to retrofit, and, thus, these flues must be either Category III or IV vent pipes. Only stainless steel Category III and IV vents are compatible with typical atmospheric combustion storage water heaters
3. A condensate drain placed near the water heater, no higher than the base of the tank, which allows the condensate removal without relying on a sump pump.
4. A gas line designed to provide 200,000 Btu/h gas supply capacity to the water heater, to accommodate future retrofit to a gas instantaneous water heater, which usually has a heat input capacity of 199,000 Btu/h or higher. Installing a larger gas line during construction is less expensive than a future gas line retrofit. Gas pipe sizing for the building needs to consider piping layout and gas supply requirements for other gas appliances (e.g., clothes dryers, furnaces, ranges and ovens, fireplace burners). The minimum gas pipe size for water heaters is ¾-inch. The exact gas piping system should be designed following the California Plumbing Code.

4.8.2.2 Solar Water Heating

§160.4(c)

Solar water-heating systems and collectors shall be certified and rated by the Solar Rating and Certification Corporation (SRCC), the International Association of Plumbing and Mechanical Officials, Research and Testing (IAPMO R&T), or by a listing agency that is approved by the Executive Director.

4.8.2.3 Commercial Boilers

§160.4(e), 120.9

Please see Section 4.2.9 for full details.

4.8.2.4 Water Piping Insulation

§160.4(f)

Multifamily and hotel/motel domestic hot water system piping must be insulated per Table [160.4-A], or Table [120.3-A] for applications above 140F. **Error! Reference source not found.**The Energy Code also requires that pipe insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

- Insulation exposed to weather shall be installed with a cover suitable for outdoor service. The cover shall be water retardant and provides shielding from solar radiation that can cause degradation of the material. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure. Adhesive tape shall not be used as protection for insulation exposed to weather.
- Insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall have a Class I or Class II vapor retarder. All penetrations and joints of which shall be sealed.
- Pipe insulation buried below grade must have a waterproof, uncrushable casing or sleeve. The Energy Code does not define uncrushability, as any material can be crushed, given enough pressure, and thus it is left to the professional judgement of the designer The internal cross-section or diameter of the casing or sleeve shall be large enough to allow for insulation of the hot water piping. Pre-insulated pipe with an integrated protection sleeve will also meet this requirement.

There are exceptions to the requirements for pipe insulation, as described below:

- Pipes completely surrounded with at least four inches of attic insulation,2 inches of crawlspace insulation, or 1 inch of wall insulation; any section of pipe not meeting this criterion must be insulated.
- Piping in walls meeting Quality Insulation Installation (QII) requirements as specified in the Reference Residential Appendix RA3.5. Otherwise, the section of pipe not meeting the QII specifications must be insulated.
- Factory-installed piping within space-conditioning equipment certified under 110.1 or 110.2.
- Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing. Insulation shall butt securely against all framing members.

4.8.3 Prescriptive Requirements Applicable to Nonresidential Occupancies

§140.5(a)&(c)

Service water heating for school buildings less than 25,000 ft^2 and less than 4 stories in climate zones 2-15 must use a heat pump water heater that meets all mandatory requirements of Sections 110.1, 110.3, and 120.3. However, bathrooms in these buildings that are served by individual water heaters may use electric instantaneous water heaters.

All other nonresidential occupancies can use a wider range of acceptable water heater types, as long as the water heater meets the mandatory requirements under Sections 110.1, 110.3, and 120.3, and the high-capacity service water heating system requirements under Section 140.5(c).

Gas service water-heating systems with a total installed input capacity of 1 MMBtu/h (1 million Btu/h) or greater must have service water-heating equipment with a thermal efficiency of 90 percent or higher. Multiple units can meet this requirement if the water-heating input provided by equipment with thermal efficiencies above and below 90 percent averages out to an input capacity-weighted average of at least 90 percent. It should be noted that individual gas water heaters of 100,000 Btu/h or less are not counted in calculating total system input or efficiency. There are 2 main exceptions from this requirement:

1. Systems that derive 25 percent of their annual water heating energy from site-solar or site-recovered sources
2. Water heaters installed in individual dwelling units

Example: WH sys has 110k @ 85%, 2x 300k @ 90%, 400k @ 95%, 90k @ 70% - wt. avg. = ~91%, because ≤ 100k is excluded, so such a system would be acceptable.

4.8.4 Prescriptive Requirements Applicable to Multifamily and Hotel/Motel Buildings

§140.5(b); 170.2(d)

For water heating systems for multifamily and hotel/motel buildings, the code references to the multifamily prescriptive requirements under Section 170.2. The executive director can also approve another water heating system that uses no more energy than one described in Sections 4.8.4.1 or 4.8.4.2 below. The following paragraphs recap these requirements.

4.8.4.1 Water Heating Systems Serving Single Dwelling Units Solar Water Heating

§170.2(d)1

Systems for individual dwelling units with recirculation distribution systems must use Demand Recirculation with a manual on/off control meeting RA4.4.9.

There are 3 options for water heating systems serving single dwelling units:

1. One 240V heat pump water heater (HPWH); a compact hot water distribution system (CHWDS) meeting RA4.4.6 is also required in climate

zones s 1 & 16. A drain water heat recovery (DWHR) device meeting RA3.6.9 is also required in climate zone 16

2. One HPWH meeting NEEA Tier 3 or higher specifications. A DWHR device meeting RA3.6.9 is also required in climate zone 16
3. A gas or propane tankless water heater of 200 kBtu/h or less

4.8.4.2 Water Heating Systems Serving Multiple Dwelling Units

§170.2(d)2&3

Systems serving multiple dwelling units must be central water heating systems with recirculation distribution systems meeting §110.3(c)2&5 (please see Sections 4.8.1.3 and 4.8.1.6 for details), able to automatically control the pump based on hot water demand and water return temperature. Water heating systems serving buildings with 8 or fewer dwelling units do not require recirculation systems.

There are 2 water heating system options:

1. HPWH with the following:
   i. Recirculation loop return connected to a recirculation loop tank
   ii. If auxiliary heating is needed, the recirculation loop tank heater must be electric and capable of multi-pass operation
   iii. If the HPWH is single-pass, the main thermal tanks must be piped in series. If multi-pass, the main thermal tanks must be piped in parallel
   iv. Main tank must be set to 135°F
   v. Recirculation loop tank temperature must be 10°F lower than that of the main tank; the recirculation loop tank water must be used to maintain the temperature before using recirculation loop tank heater
   vi. The compressor must shut off when the ambient temperature is 40°F or below.
2. A gas or propane central water heater meeting the following:
   i. In climate zones 1-9, if the input is 1MM Btu/h or greater, then any water heating equipment must have a thermal efficiency of 90% or greater. Multiple units can be used if their input capacity-weighted average of 90% or more. Water heaters of 100k Btu/h or less are not included in this calculation. There is an Exception for systems deriving 25% or more of their annual energy from site-solar or site-recovered energy.
   ii. Solar water heating (described below)

4.8.4.3 Solar Water Heating

§170.2(d)3C

Solar water heating is prescriptively required for gas or propane water heating systems serving multiple dwelling units in a motel/hotel or multifamily building. The minimum solar savings fraction (SSF) is dependent on the climate zone: 0.20 for CZ 1 through 9, and 0.35 for CZ 10 through 16. A provision allows a reduced SSF, if drain water heat recovery devices are installed. The Energy Code do not limit the solar water heating equipment or system type, as long as they are SRCC certified and meet the orientation, tilt and shading requirement specified in RA 4.4. Installation of a solar water heating system exempts high-rise multifamily and hotel/motel buildings from needing to set aside a solar zone for future solar PV installation (Exception 2 to §110.10(b)1B). The following paragraphs offer some high-level design considerations for multifamily building solar water heating systems.

A high-priority factor for solar water heating system design is component sizing. Proper sizing of the solar collectors and the solar tank ensures that the system take full advantage of the sun's energy while avoiding the problem of overheating. While the issue of freeze protection has been widely explored (development of various solar water heating system types is a reflection of this evolution), the issue of overheating is often not considered as seriously as it should be. This is especially critical for multifamily-sized systems, due to load variability.

To be conservative, the highest SSF requirement called for by the 2022 Energy Code is 35 percent. Industry standard sizing for an active system is generally 1.5 sq ft collector area per gallon capacity for solar tanks. For more detailed guidance and best practices, there are many publicly available industry design guidelines. Two such resources developed by or in association with government agencies are Building America Best Practices Series: Solar Thermal and Photovoltaic Systems[3], and California Solar Initiative – Thermal: Program Handbook[4]. Because of the new solar water heating requirement and prevalence of recirculation hot water systems in multifamily buildings, it is essential to re-iterate the importance of proper integration between the hot water recirculation system and the solar water heating system. Industry stakeholders recommend the recirculation hot water return to be connected back to the system *downstream* of the solar storage tank. This eliminates the unnecessary wasted energy used to heat up water routed back from the recirculation loop that may have been sitting in the solar water tank if no draw has occurred over a prolonged period of time.

Another design consideration is the layout and placement of collectors and the solar tank. The design should minimize the length of plumbing, and thus reduce pipe

[3] http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/41085.pdf

[4] [4] http://www.gosolarcalifornia.ca.gov/documents/CSI-Thermal_Handbook.pdf

surface areas susceptible to heat loss as well as the quantity of piping materials needed for the installation. The distance between collectors and the solar tank should also be as short as practically possible.

4.8.4.4 Dual Recirculation Loop Design

A dual-loop design is illustrated in Figure 4-32. In a dual-loop design, each loop serves half of the dwelling units. According to plumbing code requirements, the pipe diameters can be downsized compared to a loop serving all dwelling units. The total pipe surface area is effectively reduced, even though total pipe length is about the same as that of a single-loop design. For appropriate pipe sizing guidelines, refer to the Universal Plumbing Code.

Figure 4-32: Example of a Dual-Loop Recirculation System

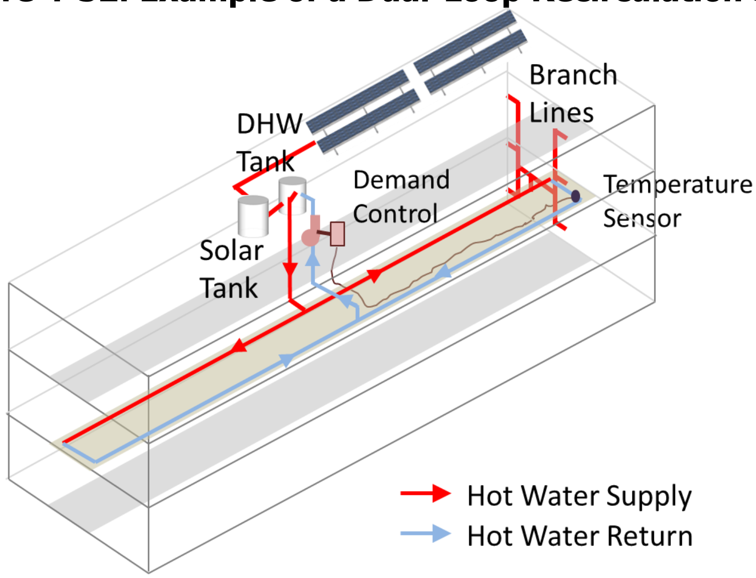
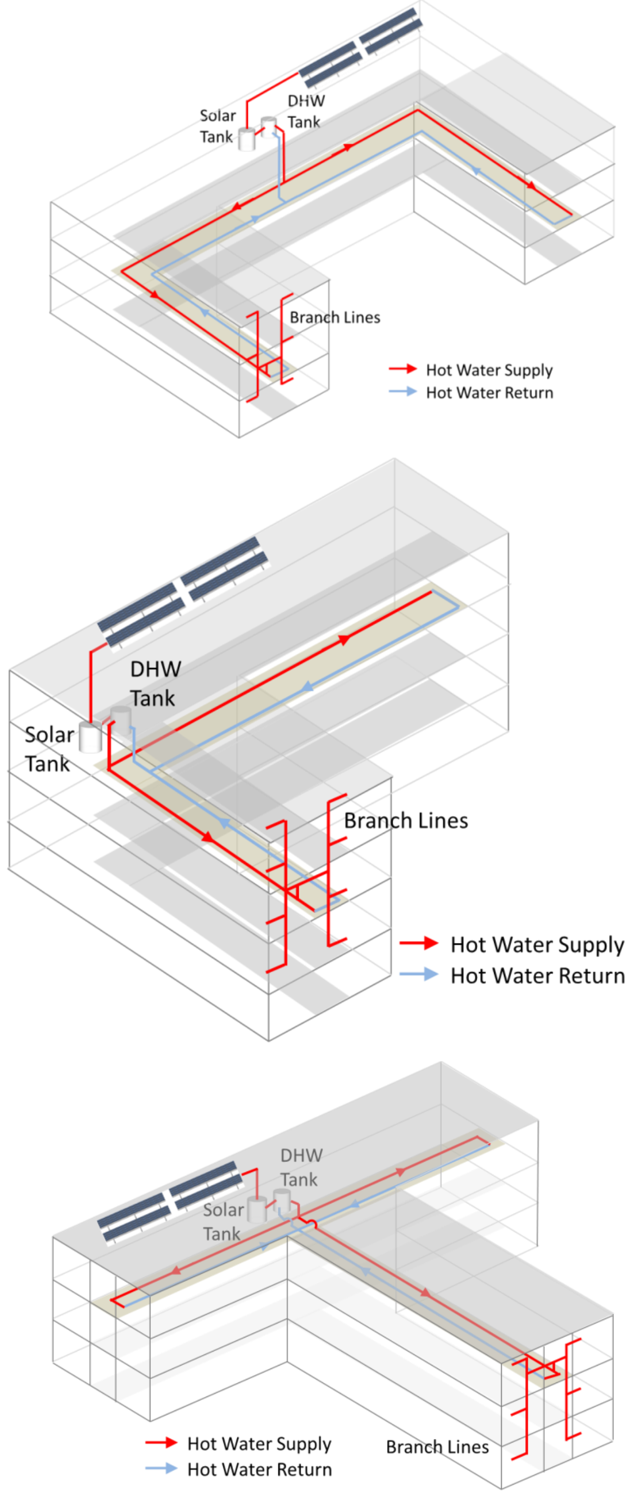


Figure 4-32 provides an example of how to implement dual-loop design in a low-rise multi-family building with a simple layout. In this example, the water heating equipment is located in the middle of the top floor with each recirculation loop serving exactly half of the building. The recirculation loops are located in the middle floor to minimize branch pipe length to each of the dwelling units. Figure 4-32 also illustrates how the solar water heating system and demand control are integrated.

For buildings with complicated layouts, an optimum design for recirculation loops depends on the building geometry. In general, the system should be designed to have each loop serving an equal number of dwelling units in order to minimize pipe sizes. For systems serving buildings with distinct sections, e.g., two wings in an "L" shaped building, it is better to dedicate a separate recirculation loop to each section. Very large buildings and buildings with more than two sections should consider using separate central water heating systems for each section or part of the building. In all cases, a simplified routing of recirculation loops should be used to keep recirculation pipes as short as possible. Figure 4-33 shows examples of dual-loop recirculation system designs in buildings that have complicated floor plans.

Figure 4-33: Examples of Dual-Loop Recirculation System Designs in Buildings That Have Complicated Floor Plans



Location of water heating equipment in the building should be carefully considered to properly implement the dual-loop design. The goal is to keep overall pipe length as short as possible. For example, for buildings that do not have complicated floor plans; the designer should consider locating the water heating equipment at the center of the building footprint rather than at one end of the building which helps to minimize the pipe length needed. If a water heating system serves several distinct building sections, the water heating equipment would preferably nest in between these sections.

With the prescriptive solar water heating requirement in the Energy Code, it is especially important to consider the integration between the hot water recirculation system and the solar water heating system. Based on feedback from industry stakeholders, most solar water heating systems are only configured to operate as a pre-heater for the primary gas water heating equipment. In other words, recirculation hot water returns are usually plumbed back to the gas water heating storage tanks, not directly into the solar tank. This means recirculation loop designs should be mostly based on the building floor plan and are relatively independent of the solar water heating system. The system's gas water heating equipment and solar tank should be located close together to avoid heat loss from the piping that connects the two systems. The preferred configuration is to place both the gas water heating equipment and solar tank on the top floor near the solar collector so that the total system pipe length can be reduced. Minimizing pipe length helps to reduce domestic hot water (DHW) system energy use as well as system plumbing cost.

4.8.4.5 Demand Recirculation Control

The prescriptive requirement for DHW systems serving multiple dwelling units requires the installation of a demand recirculation control to minimize pump operation, based on hot water demand and recirculation return temperatures, instead of the manual demand controls used in single dwelling units. The temperature sensor should be installed at the last branch pipe along the recirculation loop to measure the hot water return temperature most accurately.

Any system that does not meet the prescriptive requirements must instead meet the standard design building energy budget or otherwise follow the performance compliance approach.

4.8.5 Pool and Spa Heating Systems

§110.4

Pool and spa heating systems must be certified by the manufacturer and listed by the Energy Commission as having:

1. For equipment subject to state or federal appliance efficiency regulations, a listing in MAEDbS, showing compliance
2. An on/off switch mounted on the outside of the heater in a readily accessible location that allows the heater to be shut off without adjusting the thermostat setting

3. A permanent, easily readable, and weatherproof plate or card that gives instructions for the energy efficient operation of the pool or spa, and for the proper care of the pool or spa water when a cover is used.

No electric resistance heating, except:

a) Listed packaged units with fully insulated enclosures and tight fitting covers that are insulated to at least R-6. Listed package units are defined in the National Electric Code and are typically sold as self-contained, UL Listed spas.

b) Pools or spas deriving at least 60 percent of the annual heating energy from site solar energy or recovered energy.

If a pool or spa does not currently use solar heating collectors for heating of the water, piping must be installed to accommodate any future installation. Contractors can choose one of three options to allow for the future addition of solar heating equipment:

1. Leave at least 36 inches of pipe between the filter and heater to allow for the future addition of solar heating equipment
2. Plumb separate suction and return lines to the pool dedicated to future solar heating
3. Install built-up or built-in connections for future piping to solar water heating, (example: a built-in connection could be a capped off tee fitting between the filter and heater)

Pool and spa heating systems with gas or electric heaters for outdoor use must use a pool cover. The pool cover must be fitted and installed during the final inspection.

All pool systems must be installed with the following:

1. Directional inlets must be provided for all pools that adequately mix the pool water.
2. A time switch or similar control mechanism shall be provided for pools to control the operation of the circulation control system, to allow the pump to be set or programmed to run in the off-peak demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

§110.5

Pool and spa heaters are not allowed to have pilot lights.

4.8.5.1 Pool and Spa Heating System Requirements Specific to Multifamily Buildings

§160.7(b)

Pool and spa systems available to multiple tenants or to the public must comply with the applicable requirements of §110.4, detailed above.

Pool and spa systems installed for exclusive use by a single tenant shall comply with the applicable requirements of §150.0(p)

4.9 Performance Approach

Under the performance approach, the energy use of the building is modeled using a compliance software program approved by the Energy Commission. Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program. All compliance software programs, however, are required to have the same basic modeling capabilities.

More information on how to model the mechanical systems and components are included in Chapter 9, Performance Approach, and in the program vendor's compliance supplement.

The compliance rules used by the computer methods in generating the energy budget and compliance credits are based on features required for prescriptive compliance. Detailed information can be found in the Nonresidential Alternative Calculation Methods (ACM) Approval Manual.

There are minimum modeling capabilities required for programs that are used for the performance approach. All certified programs are tested for conformance with the requirements of the Nonresidential ACM. The designer has to use an approved program to show compliance.

Compliance is shown by running two models: a base case budget building that nominally meets the mandatory and prescriptive requirements and a proposed building that represents the actual proposed envelope, lighting, and mechanical systems of the building. To create a level playing field the base case and proposed designs are compared using the same assumptions of occupancy, proscribed climatic conditions and operating schedules. The results are compared using standardized time of use rates, or TDV of energy cost.

The proposed building complies if its annual source Energy and TDV energy is less than or equal to that of the budget building. Reference Appendix JA3 describes the derivation of the TDV energy multipliers.

Compliance in the Performance Approach is across all building systems. The design team can use more glass than with the prescriptive approach and comply by making a more efficient HVAC system. Energy can be traded off between prescriptive requirements in the envelope, HVAC system, indoor lighting, and covered processes.

The alternative calculation method defines the modeling rules for developing the base-case model of the building and mechanical systems. The base-case HVAC system(s) is modeled on a system(s) according to occupancy type, floor area of building, number of floors, and zoning.

The following are some examples of how to get credit in the Performance Approach from HVAC systems:

- Use of high efficiency equipment that exceeds the minimum requirements of §110.1 and §110.2
- Application of economizers where they are not required
- Oversizing ducts and pipes to reduce fan and pump energy
- Use of heat recovery for space or water heating
- Use of thermal energy storage systems or building mass to move cooling off peak
- Reduce reheating and recooling

Use of thermally driven cooling equipment, such as absorption chillers.

4.10 Additions and Alterations

4.10.1 Overview

This section addresses how the Energy Code apply to mechanical systems for additions and alterations to existing buildings.

Application of the Energy Code to existing buildings is often more difficult than for new buildings because of the wide variety of conditions that can be experienced in the field. In understanding the requirements, two general principles apply:

1. Existing systems or equipment are not required to meet the Energy Code.
2. New systems and equipment are required to meet both the mandatory measures and the prescriptive requirements or the performance requirements as modeled in conjunction with the envelope and lighting design.

When heating, cooling or service water heating are provided for an alteration or addition by expanding an existing system, generally, that existing system need not comply with the mandatory measures or prescriptive requirements. However, any altered component must meet all applicable mandatory measures and prescriptive requirements.

4.10.1.1 Relocation of Equipment

When existing heating, cooling, or service water heating systems or components are moved within a building, the existing systems or components do not need to comply with mandatory measures nor with the prescriptive or performance compliance requirements.

Performance approach may also be used to demonstrate compliance for alterations. Refer to Chapter 11, Performance Approach, for more details.

4.10.2 Mandatory Measures – Additions and Alterations

New mechanical equipment or systems in additions and/or alterations must comply with the mandatory measures as listed below. Additional information on these requirements is provided in earlier sections of this Chapter.

Table 4-14: Requirements for Additions and Alterations

Mandatory Measure	Application to Additions and Alterations
§110.1 – Mandatory requirements for Appliances (see Section 4.2)	The California Appliance Efficiency Regulations apply to small to medium sized heating equipment, cooling equipment and water heaters. These requirements are enforced for all equipment sold in California and therefore apply to all equipment used in additions or alterations.
§110.2 – Mandatory Requirements for Space-Conditioning Equipment (see Section 4.2)	This section sets minimum efficiency requirements for equipment not covered by §110.1. Any equipment used in additions or alterations must meet these efficiency requirements.
§110.3 – Mandatory Requirements for Service Water-Heating Systems and Equipment (see Section 4.2)	This section sets minimum efficiency and control requirements for water heating equipment. It also sets requirements for recirculating hot water distribution systems. All new equipment installed in additions and/or alterations shall meet the requirements. The recirculation loop requirements of §110.3(c)5 apply when water heating equipment and/or plumbing is changed.
§110.4 – Mandatory Requirements for Pool and Spa Heating Systems and Equipment (see Section 4.8.5).	The pool requirements of §110.4 do not apply for maintenance or repairs of existing pool heating or filtration systems.
§110.5 – Natural Gas Central Furnaces, Cooking Equipment, and Pool and Spa Heaters: Pilot Lights Prohibited (see Section 4.2)	Any new gas appliances installed in additions or alterations shall not have a standing pilot light, unless one of the exceptions in §110.5 is satisfied.
§120.1 – Requirements for Ventilation (see Section 4.3)	Systems that are altered or new systems serving an addition shall meet the outside air ventilation and control requirements, as applicable. When existing systems are extending to serve additions or when occupancy changes in an existing building (such as the conversion of office space to a large conference room), the outside air settings at the existing air handler may need to be modified and, in some cases, new controls may be necessary.

§120.2 – Required Controls for Space-Conditioning Systems (see Section 4.5)	§120.2(a) requires a thermostat for any new zones in additions or new zones created in an alteration. §120.2(b) requires that new thermostats required by §120.2(a) meet the minimum requirements. §120.2(c) applies to hotel/motel guest rooms only when the system level controls are replaced; replacement of individual thermostats are considered a repair. §120.2(d) requires that new heat pumps used in either alterations or additions have controls to limit the use of electric resistance heat, per §110.2(b). This applies to any new heat pump installed in conjunction with an addition and/or alteration. §120.2(e) requires that new systems in alterations and additions have scheduling and setback controls. §120.2(f) requires that outside air dampers automatically close when the fan is not operating or during unoccupied periods and remain closed during setback heating and cooling. This applies when a new system or air handling unit is replaced in conjunction with an addition or alteration. §120.2(g) requires that areas served by large systems be divided into isolation areas so that heating, cooling and/or the supply of air can be provided to only the isolation areas that need it and other isolation areas can be shut off. This applies to additions larger than 25,000 sq ft and to the replacement of existing systems when the total area served is greater than 25,000 sq ft. §120.2(h) requires that direct digital controls (DDC) that operate at the zone level be programmed to enable non-critical loads to be shed during electricity emergencies. This requirement applies to additions and/or alterations anytime DDC are installed that operate at the zone level. §120.2(i) requires a Fault Detection and Diagnostic System for all newly added air handler units equipped with an economizer and mechanical cooling capacity equal to or greater than 54,000 Btu/hr in accordance with §120.2(i)2. through §120.2(i)8. §120.2(j) requires DDC in newly constructed buildings additions or alterations for certain applications and qualifications. It also requires certain capabilities for mandated DDC systems. §120.2(k) requires optimum start/stop when DDC is to the zone level.
§120.3 – Requirements for Pipe Insulation (see Section 4.4)	The pipe insulation requirements apply to any new piping installed in additions or alterations.
§120.4 – Requirements for Air Distribution System Ducts and Plenums (see Section 4.4)	The duct insulation, construction and sealing requirements apply to any new ductwork installed in additions or alterations.
§120.5 – Required Nonresidential Mechanical System Acceptance (See Chapter 13)	Acceptance requirements are triggered for systems or equipment installed in additions and alterations the same way they are for new buildings or systems.
§120.9 - Mandatory Requirements for Commercial Boilers (see Section 4.2.9)	The requirements apply to any new commercial boilers installed in additions or alterations.
§160.4 – Mandatory Requirements for Water Heating Systems (Multifamily) (see Section 4.8.2)	All new equipment installed in additions shall meet the requirements. Newly installed piping and existing accessible piping must meet the insulation requirements of §160.4(f) When existing water heating systems are expanded to serve an alteration, or moved within a building, the requirements of §160.4 do not apply to those existing systems

§160.7 – Mandatory Requirements for Covered Processes (Multifamily) (see Section 4.8.5.1)	All new equipment installed in additions shall meet the requirements. When existing pool & spa systems are expanded to serve an alteration, or moved within a building, the requirements of §160.4 do not apply to those existing systems

4.10.3 Requirements for Additions

4.10.3.1 Prescriptive Approach

All new additions must comply with the following prescriptive requirements:

- §140.4 – Prescriptive Requirements for Space Conditioning Systems, except the condensing boiler system requirements of 140.4(k)8.
- §140.5 – Prescriptive Requirements for Service Water-Heating Systems, except the requirements of 140.5(c).
- §180.1 – Prescriptive Requirements for Multifamily Buildings
  - §180.1(d)3 – Prescriptive Requirements for Water Heaters in Multifamily Additions

For more detailed information about the prescriptive requirements, refer to following sections of this chapter:

- Section 4.5.2 - HVAC Controls
- Section 4.6.2 - HVAC System Requirements

4.10.3.2 Performance Approach

The performance approach may also be used to demonstrate compliance for new additions. When using the performance approach for additions §141.0(a)2B defines the characteristics of the standard design building.

For more detailed information, see Chapter 11, Performance Approach.

4.10.3.3 Acceptance Tests

Acceptance tests must be conducted on the new equipment or systems when installed in new additions. For more detailed information, see Chapter 13.

4.10.4 Requirements for Alterations

4.10.4.1 Prescriptive Requirements – New or Replacement Equipment

New space conditioning systems or components other than space conditioning ducts must meet applicable prescriptive requirements of Sections 4.5.2 and 4.6.2 (§140.4).

Minor equipment maintenance (such as replacement of filters or belts) does not trigger the prescriptive requirements. Equipment replacement (such as the installation of a new air handler or cooling tower) would be subject to the prescriptive requirements. Another example is when an existing VAV system is expanded to serve additional zones, the new VAV boxes are subject to zone controls of Section 4.5. Details on prescriptive requirements may be found in other sections of this chapter.

Replacements of electric resistance space heaters for high-rise residential apartments are also exempt from the prescriptive requirements. Replacements of electric heat or electric resistance space heaters are allowed where natural gas is not available.

Alterations to service water heating in nonresidential and hotel/motel buildings must meet all applicable requirements of §140.5(a)&(b) with the exception of the solar water heating requirements in §170.2(d)3.

Alterations to service water heating systems serving individual dwelling units in multifamily buildings must meet all requirements of §180.2(b)3:

- Newly installed piping and accessible existing piping must meet the insulation requirements of §160.4(f) (see Section 4.8.2.4)
- If a recirculation distribution system is used, it must be a Demand Recirculation system with a manual on/off control meeting Reference Appendix RA4.4.9
- The system must be one of the following:
  a. A natural gas or propane water heater
  b. A single HPWH with the tank located indoors, placed on an incompressible, rigid surface insulated to R-10 or higher, and with either an interface meeting §110.12(a) requirements, or an ANSI/CTA-2045-B communication port
  c. A single HPWH meeting NEEA Tier 3 or higher specifications
  d. If the existing water heater is an electric resistance water heater, a consumer electric water heater
  e. A water heating system approved by the Executive Director as using no more energy than the options a-c listed above; if no gas is connected at the existing water heater's location, then a system approved as using no more energy than option d above

For alterations there are special rules for:

1. New or Replacement Space Conditioning Systems or Components in §141.0(b)2C.
2. Altered Duct Systems in §141.0(b)2D.
3. Altered Space – Conditioning Systems in §141.0(b)2E.

   i.

4.10.4.2 Prescriptive Requirements – Air Distribution Ducts

§141.0(b)2D and §180.2(b)2Bii

When new or replacement space-conditioning ducts are installed to serve an existing building, the new ducts shall meet the requirements of Section 4.4 (e.g., insulation levels, sealing materials and methods, and duct leakage testing).

If the ducts are added to a pre-existing duct system that serves less than 5,000 sq ft and more than 25 percent of the ductwork is outdoors or in unconditioned area, the system must be tested to leak no more than 15 percent. The description of the test method can be found in Section 2.1.4.2 of Reference Nonresidential Appendix NA2. The air distribution acceptance test associated with this can be found in Reference Nonresidential Appendix NA7. This and all acceptance tests are described in Chapter 13 of this manual. If the new ducts are added to a duct system that serves more than 5,000 sq ft or less than 25 percent of the ductwork is outdoors or in unconditioned space, then the new ductwork must meet the duct leakage testing requirements of CMC Section 603.10.1.

1. If it is not possible to meet the duct sealing requirements of §141.0(b)2Dii, all accessible leaks shall be sealed and verified through a visual inspection and smoke test performed by a certified HERS rater utilizing the methods specified in Reference Nonresidential Appendix NA 2.1.4.2.2.

Exception: Existing duct systems that are extended, constructed, insulated, or sealed with asbestos.

Once the ducts have been sealed and tested to leak less than the above amounts, a HERS rater will be contacted by the contractor to validate the accuracy of the duct sealing measurement on a sample of the systems repaired as described in Reference Nonresidential Appendix NA1. Certified Acceptance Test Technicians (ATT may perform these field verifications only if the Acceptance Test Technician Certification Provider (ATTCP) has been approved to provide this service.

4.10.4.3 Prescriptive Requirements – Space-Conditioning Systems Alterations

§141.0(b)2E and §180.2(b)2Biii

Similar requirements apply to ducts upon replacement of small (serving less than 5,000 sq ft) constant volume HVAC units or their components (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil). The duct sealing requirements are for those systems where over 25 percent of the duct area is outdoors or in unconditioned areas including attic spaces and above insulated ceilings.

One can avoid sealing the ducts by insulating the roof and sealing the attic vents as part of a larger remodel, thereby creating a conditioned space within which the ducts are located, which no longer meets the criteria of §140.4(l).

When a space conditioning system is altered by the installation or replacement of space conditioning equipment (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil), the duct system that is connected to the new or replaced space conditioning equipment, shall be sealed, as confirmed through field verification and diagnostic testing in accordance with procedures for duct sealing of existing duct systems as specified in the Reference Nonresidential Appendix NA1, to one of the requirements of §141.0(b)2D. In addition, the system shall include a setback thermostat that meets requirements of §110.12(a).

There are three exceptions to this requirement:

1. Buildings altered so that the duct system no longer meets the criteria of §140.4(l)1, 2, and 3. Ducts would no longer have to be sealed if the roof deck was insulated and attic ventilation openings sealed.
2. Duct systems that are documented to have been previously sealed as confirmed through field verification and diagnostic testing in accordance with procedures in Reference Nonresidential Appendix NA2.
3. Existing duct systems constructed, insulated, or sealed with asbestos.

For all altered unitary single zone, air conditioners, heat pumps, and furnaces where the existing thermostat does not comply with §110.12(a), the existing thermostat must be replaced with one that does comply. All newly installed space-conditioning systems requiring a thermostat shall be equipped with a thermostat that complies with §110.12(a). A thermostat compliant with §110.12(a) is also known as an occupant controlled smart thermostat, which is capable of responding to demand response signals in the event of grid congestion and shortages during high electrical demand periods.

4.10.4.4 Performance Approach

When using the performance approach for alterations, see §141.0(b)3.

4.10.4.5 Acceptance Tests

Acceptance tests must be conducted on the new equipment or systems when installed in new additions. For more detailed information, see Chapter 13.

Example 4-52

Question

A maintenance contractor comes twice a year to change the filters and check out the rooftop packaged equipment that serves an office. Do the Energy Code apply to this type of work?

Answer

No. The Energy Code does not apply to general maintenance such as replacing filters, belts, or other components. However, if the rooftop unit wears out and needs to be replaced, then the new unit would have to meet the equipment efficiency requirements of §110.2, the mandatory requirements of §120.1-§120.4 and the prescriptive requirements of §140.4.

Example 4-53

Question

A building is being renovated and the old heating system is being entirely removed and replaced with a new system that provides both heating and cooling. How do the Energy Code apply?

Answer

Yes. All of the requirements of the Energy Code apply in the same way they would if the system were in a new building.

Example 4-54

Question

A 10,000 sq ft addition is being added to a 25,000 sq ft building. The addition has its own rooftop HVAC system. The system serving the existing building is not being modified. How do the Energy Code apply?

Answer

The addition is treated as a separate building and all the requirements of the Energy Code apply to the addition. None of the requirements apply to the existing system or existing building since it is not being modified.

Example 4-55

Question

A 3,000 sq ft addition is being added to a 50,000 sq ft office. The existing packaged VAV system has unused capacity and will be used to serve the addition as well as the existing building. This system has DDC at the zone level and an air side economizer.

Ductwork will be extended from an existing trunk line and two additional VAV boxes will be installed with hot water reheat. Piping for reheat will be extended from existing branch lines. How does the Energy Code apply?

Answer

The general rule is that the Energy Code applies to newly constructed buildings, additions and alterations, but not to existing systems that are not being modified (altered). In this case, Energy Code requirements would not apply to the existing Packaged VAV. However, the ductwork serving the addition would have to be sealed and insulated according to the requirements of §120.4 and the hot water piping would have to be insulated according to the requirements of §120.3 In addition, the new thermostats would have to meet the requirements of §120.2 (a), (b), and (h); ventilation would have to be provided per §120.1, fractional fan motors in the new space would have to comply with §140.4(c)4; and the new VAV boxes would have to meet the requirements of 140.4(d).

Example 4-56

Question

In the previous example (3,000 sq ft addition is added to a 50,000 sq ft office), how do the outside air ventilation requirements of §120.1 apply?

Answer

The outside air ventilation rates specified in §120.1 apply at the air handler. When existing air handlers are extended to serve additional space, it is necessary to reconfigure the air handler to assure that the outside air requirements of §120.1 are satisfied for all the spaces served. In addition, the acceptance requirements for outside air ventilation are also triggered (see Chapter 12). It would be necessary to evaluate the occupancies both in the addition and the existing building to determine the minimum outside air needed to meet the requirements of §120.1. The existing air handler would have to be controlled to assure that the minimum outside air is delivered to the spaces served by the air handler for all positions of the VAV boxes. For more detailed information, see Section 4.3.Additional controls may need to be installed at the air handler to meet this requirement.

Example 4-57

Question

In the previous example, the 3,000 sq ft addition contains a large 400 sq ft conference room. What additional requirements are triggered in this instance?

Answer

In this case, the demand control requirements of §120.1(d)3 would apply to the conference room, since it has an occupant density greater than 25 persons per 1,000 sq ft and the packaged VAV system serving the building has an air economizer. If the existing system did not have an air economizer, then the demand control requirements would not apply. A CO2 sensor would need to be provided in the conference room to meet this requirement. The programming on the OSA damper would have to be modified to increase OSA if the zone ventilation wasn't satisfied.

Example 4-58

Question

An existing building has floor-by-floor VAV systems with no air side economizers. The VAV boxes also have electric reheat. Outside air is ducted to the air handlers on each floor which is adequate to meet the ventilation requirements of §120.1, but not large enough to bring in 100 percent outside air which would be needed for economizer operation. A tenant space encompassing the whole floor is being renovated and new ductwork and new VAV boxes are being installed. Does the economizer requirement of §140.4(e) apply? Does the restriction on electric resistance heat of §140.4(g) apply?

Answer

Since the air handler is not being replaced, the economizer requirement of §140.4(e) does not apply. If in the future the air handler were to be replaced, the economizer requirement would need to be satisfied. However, for systems such as this a water side economizer is often installed instead of an air side economizer. The electric resistance restriction of §140.4(g) does apply unless the Exception 2 to §141.0(a) applies. This exception permits electric resistance to be used for the additional VAV boxes as long as the total capacity of the electric resistance system does not increase by more than 150 percent.

Example 4-59

Question

In the previous example, the building owner has decided to replace the air handler on the floor where the tenant space is being renovated because the new tenant has electronic equipment that creates more heat than can be removed by the existing system. In this case, does the economizer requirement of §140.4(e) apply?

Answer

In this case, because the air handler is being replaced, the economizer requirement does apply. The designer would have a choice of using an air-side economizer or a water-side economizer. The air side economizer option would likely require additional or new ductwork to bring in the necessary volume of outside air. The feasibility of a water economizer will depend on the configuration of the building. Often a cooling tower is on the roof and chillers are in the basement with chilled water and condenser water lines running in a common shaft. In this case, it may be possible to tap into the condenser water lines and install a water economizer. However, pressure controls would need to be installed at the take offs at each floor and at the chiller.

Example 4-60

Question

Four hundred tons of capacity is being added to an existing 800-ton chilled water plant. The existing plant is air cooled (two 400-ton air cooled chillers). Can the new chillers also be air cooled?

Answer

No. The requirements of §140.4(j) apply in this case and a maximum of 300 tons of air-cooled chillers has been reached (and exceeded) at this plant. The remainder has to be water cooled. They would not have to retrofit the plant to replace either of the existing air-cooled chillers with water cooled. If one of the existing air-cooled chillers failed in the future, it would have to be replaced with a water-cooled chiller. If both air-cooled chillers failed, they could only provide 300 tons of air-cooled capacity.

4.11 Glossary/Reference

Terms used in this chapter are defined in Reference Joint Appendix JA1. Definitions that appear below are either not included within Reference Joint Appendix JA1 or expand on the definitions.

4.11.1 Definitions of Efficiency

Minimum efficiency requirements that regulated appliances and other equipment must meet are in §110.1 and §110.2. The following describes the various measurements of efficiency used in the Energy Code.

The purpose of space-conditioning and water-heating equipment is to convert energy from one form to another, and to regulate the flow of that energy. Efficiency is a measure of how effectively the energy is converted or regulated. It is expressed as the ratio:

Equation 4-11

$$Efficiency = \frac{Output}{Input}$$

The units of measure in which the input and output energy are expressed may be either the same or different and vary according to the type of equipment. The Energy Code use several different measures of efficiency.

Combustion efficiency is defined in the Appliance Efficiency Regulations as follows:

Combustion efficiency of a space heater means a measure of the percentage of heat from the combustion of gas or oil that is transferred to the space being heated or lost as jacket loss, as determined using the applicable test method in Section 1604(e) of Title 20.

Boiler means a space heater that is a self-contained appliance for supplying steam or hot water primarily intended for space-heating. Boiler does not include hot water supply boilers.

Where boilers used for space heating, they are considered to be a form of space heater.

Thermal or combustion efficiency is used as the efficiency measurement for gas and oil boilers with rated input greater than or equal to 300,000 Btu/hr. It is a measure of the percent of energy transfer from the fuel to the heat exchanger (HX). Input and output energy are expressed in the same units so that the result has non-dimensional units:

Equation 12

$$\text{\% Combustion Eff} = \frac{\text{(Energy to HX) x 100}}{\text{Total Fuel Energy Input}}$$

Combustion efficiency does not include losses from the boiler jacket. It is strictly a measure of the energy transferred from the products of combustion.

Fan Power Index is the power consumption of the fan system per unit of air moved per minute (W/cfm) at design conditions.

Thermal Efficiency is defined in the Appliance Efficiency Regulations as a measure of the percentage of heat from the combustion of gas, which is transferred to the space or water being heated as measured under test conditions specified. The definitions from the Appliance Efficiency Regulations are:

1. Thermal Efficiency of a space heater means a measure of the percentage of heat from the combustion of gas or oil that is transferred to the space being heated, or in the case of a boiler, to the hot water or steam, as determined using the applicable test methods in Section 1604(e).
2. Thermal Efficiency of a water heater means a measure of the percentage of heat from the combustion of gas or oil that is transferred to the water, as determined using the applicable test method in Section 1604(f).
3. Thermal Efficiency of a pool heater means a measure of the percentage of heat from the input that is transferred to the water, as determined using the applicable test method in Section 1604(g).

Equation 4-13

$$\%\ Thermal\ Efficiency\ =\ \frac{(Energy\ Transferred\ to\ Medium)}{(Total\ Fuel\ Input)}$$

4.11.2 Definitions of Spaces and Systems

The concepts of spaces, zones, and space-conditioning systems are discussed in this subsection.

Fan System is a fan or collection of fans that are used in the scope of the prescriptive requirement for fan-power limitations. Fan systems, as defined in §140.4(c), all fans in the system that are required to operate at design conditions in order to supply air from the heating or cooling source to the conditioned space, and to return it back to the source or to exhaust it to the outdoors. For cooling systems this includes supply fans, return fans, relief fans, fan coils, series-style fan powered boxes, parallel-style fan powered boxes and exhaust fans. For systems without cooling this includes supply fans, return fans, relief fans, fan coils, series-style fan powered boxes, parallel-style fan powered boxes and exhaust fans. Parallel-style fan-powered boxes are often not included in a terminal unit where there is no need for heating as the fans are only needed for heating.

Space is not formally defined in the Energy Code but is considered to be an area that is physically separated from other areas by walls or other barriers. From a mechanical perspective, the barriers act to inhibit the free exchange of air with other spaces. The term space may be used interchangeably with room.

Space Conditioning zone is a space or group of spaces within a building with sufficiently similar comfort conditioning requirements so that comfort conditions, as specified in §140.4(b)3, as applicable, can be maintained throughout the zone by a single controlling device. It is the designer's responsibility to determine the zoning; in most cases each building exposure will consist of at least one zone. Interior spaces that are not affected by outside weather conditions usually can be treated as a single zone.

A building will generally have more than one zone. For example, a facility having 10 spaces with similar conditioning (that are heated and cooled by a single space-conditioning unit using one thermostat) has one zone. However, if a second thermostat and control damper, or an additional mechanical system, is added to separately control the temperature within any of the 10 spaces, then the building has two zones.

Space-Conditioning System is used to define the scope of the requirements of the Energy Code. It is a catch-all term for mechanical equipment and distribution systems that provide (either collectively or individually) heating, ventilating, or cooling within or associated with conditioned spaces in a building. HVAC equipment is considered part of a space-conditioning system if it does not exclusively serve a process within the building. Space-conditioning systems include general and toilet exhaust systems.

Space-conditioning systems may encompass a single HVAC unit and distribution system (such as a package HVAC unit) or include equipment that services multiple HVAC units (such as a central outdoor air supply system, chilled water plant equipment or central hot water system).

4.11.3 Types of Air

Exhaust Air is air being removed from any space or piece of equipment and conveyed directly to the atmosphere by means of openings or ducts. The exhaust may serve specific areas (such as toilet rooms) or may be for a general building relief, such as an economizer.

Make-up Air is air provided to replace air being exhausted.

Mixed Air is a combination of supply air from multiple air streams. The term mixed air is used in the Energy Code in an exception to the prescriptive requirement for space conditioning zone controls, §140.4(d). In this manual the term mixed air is also used to describe a combination of outdoor and return air in the mixing plenum of an air handling unit.

Outdoor Air is air taken from outdoors and not previously circulated in the building. For ventilation, outdoor air is used to flush out pollutants produced by the building materials, occupants, and processes. To ensure that all spaces are adequately ventilated with outdoor air, the Energy Code requires that each space be adequately ventilated, see Section 4.3.

Return Air is air from the conditioned area that is returned to the conditioning equipment either for reconditioning or exhaust. The air may return to the system through a series of ducts, or through plenums and airshafts.

Supply Air is air being conveyed to a conditioned area through ducts or plenums from a space-conditioning system. Depending on space requirements, the supply may be heated, cooled, or neutral.

Transfer Air is air that is transferred directly from either one space to another or from a return plenum to a space. Transfer air is a way to meet the ventilation requirements at the space level and is an acceptable method of ventilation per §120.1. It works by transferring air with a low level of pollutants (from an over-ventilated space) to a space with a higher level of pollutants, see Section 4.3).

4.11.4 Air-Delivery Systems

Space-conditioning systems can be grouped according to how the airflow is regulated as follows:

Constant Volume System is a space-conditioning system that delivers a fixed amount of air to each space. The volume of air is set during the system commissioning.

Variable Air Volume (VAV) System is a space conditioning system that maintains comfort levels by varying the volume of conditioned air to the zones served. This system delivers conditioned air to one or more zones. There are two styles of VAV systems, single-duct VAV (where mechanically cooled air is typically supplied and reheated through a duct mounted coil) and dual-duct VAV (where heated and cooled streams of air are blended at the zone level). In single-duct VAV systems the duct serving each zone is provided with a motorized damper that is modulated by a signal from the zone thermostat. The thermostat also controls the reheat coil. In dual-duct VAV systems the ducts serving each zone are provided with motorized dampers that blend the supply air based on a signal from the zone thermostat.

Pressure Dependent VAV Box is a system that has an air damper whose position is controlled directly by the zone thermostat. The actual airflow at any given damper position is a function of the air static pressure within the duct. Because airflow is not measured, this type of box cannot precisely control the airflow at any given moment: a pressure dependent box will vary in output as other boxes on the system modulate to control their zones.

Pressure Independent VAV Box is a system with an air damper whose position is controlled on the basis of measured airflow. The set point of the airflow controller is, in turn, reset by a zone thermostat. A maximum and minimum airflow is set in the controller, and the box modulates between the two according to room temperature.

4.11.5 Return Plenums

Return Air Plenum is an air compartment, or chamber, other than the occupied space being conditioned- to which one or more ducts are connected and which forms part of either the supply air, return air or exhaust air system. The return air temperature is usually within a few degrees of space temperature. This may include uninhabited crawl spaces, areas above a ceiling or below a floor, air spaces below raised floors of computer/data processing centers, or attic spaces.

4.11.6 Zone Reheat, Recool, and Air Mixing

When a space-conditioning system supplies air to one or more zones, different zones may be at different temperatures because of varying loads. Temperature regulation is normally accomplished by varying the conditioned air supply (variable volume); varying the temperature of the air delivered, or by a combination of supply and temperature control. With multiple zone systems, the ventilation requirements or damper control limitations may cause the cold air supply to be higher than the zone load. This air is tempered through reheat or mixing with warmer supply air to satisfy the actual zone load. The regulations in §140.4(c) limits the amount of energy used to simultaneously heat and cool the same zone as a basis of zone temperature control.

Zone reheat is the heating of air that has been previously cooled by cooling equipment, systems, or an economizer. A heating device, usually a hot water coil, is placed in the zone supply duct and is controlled via a zone thermostat. Electric reheat is sometimes used but is severely restricted by the Energy Code.

Zone recool is the cooling of air that has been previously heated by space conditioning equipment or systems serving the same building. A chilled water or refrigerant coil is usually placed in the zone supply duct and is controlled via a zone thermostat. Re-cooling is less common than reheating.

Zone Air Mixing occurs when more than one stream of conditioned air is combined to serve a zone. This can occur at the HVAC system (e.g., multizone), in the ductwork (e.g., dual-duct system) or at the zone level (such as a zone served by a central cooling system and baseboard heating). In some multizone and dual duct systems an unconditioned supply is used to temper either the heating or cooling air through mixing. The regulation in §140.4(c) only applies to systems that mix heated and cooled air.

4.11.7 Economizers

4.11.7.1 Air Economizers

An air economizer is a ducting arrangement and automatic control system that allows a cooling supply fan system to supply outside air to reduce or eliminate the need for mechanical cooling.

When the compliance path chosen for meeting the Energy Code requires an economizer, the economizer must be integrated into the system so that it is capable of satisfying part of the cooling load while the rest of the load is satisfied by the refrigeration equipment. The Energy Code also require that all new economizers meet the Acceptance Requirements for Code Compliance before a final occupancy permit may be granted. The operation of an integrated air economizer is diagrammed in **Figure 4-34**.

When outdoor air is sufficiently cold, the economizer satisfies all cooling demands on its own. As the outdoor temperature (or enthalpy) rises, or as system cooling load increases, a point may be reached where the economizer is no longer able to satisfy the entire cooling load. At this point the economizer is supplemented by mechanical refrigeration, and both operate concurrently. Once the outside dry bulb temperature (for temperature-controlled economizer) or enthalpy (for enthalpy economizers) exceeds that of the return air or a predetermined high limit, the outside air intake is reduced to the minimum required for ventilation purposes, and cooling is satisfied by mechanical refrigeration only.

Nonintegrated economizers cannot be used to meet the economizer requirements of the prescriptive compliance approach. In nonintegrated economizer systems, the economizer may be interlocked with the refrigeration system to prevent both from operating simultaneously. The operation of a nonintegrated air economizer is diagrammed in Figure 4-33. Nonintegrated economizers can only be used if they comply through the performance approach.

Figure 4-34: Integrated Air Economizer

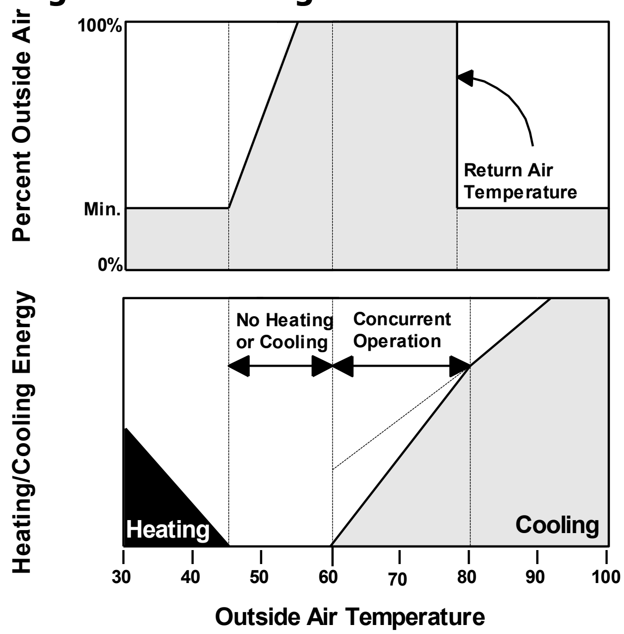
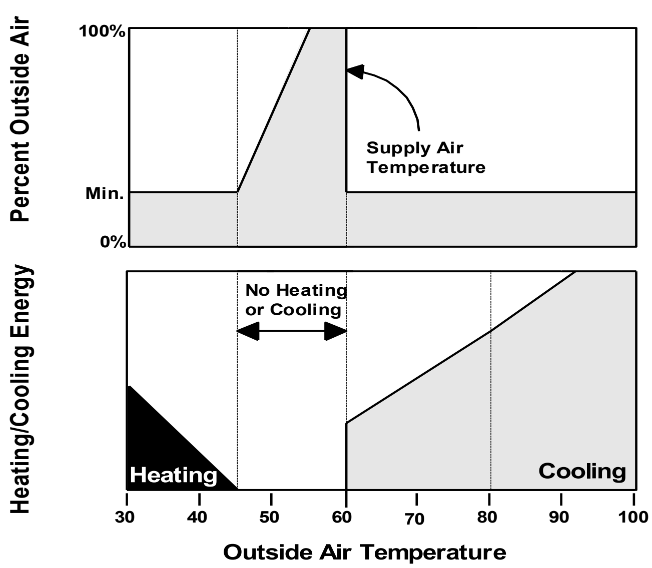


Figure 4-35: Nonintegrated Air Economizer



4.11.7.1.1.1 Water Economizers

A water economizer is a system by which the supply air of a cooling system is cooled directly or indirectly by evaporation of water, or other appropriate fluid, in order to reduce or eliminate the need for mechanical cooling.

As with an air economizer, a water economizer must be integrated into the system so that the economizer can supply a portion of the cooling concurrently with the refrigeration system.

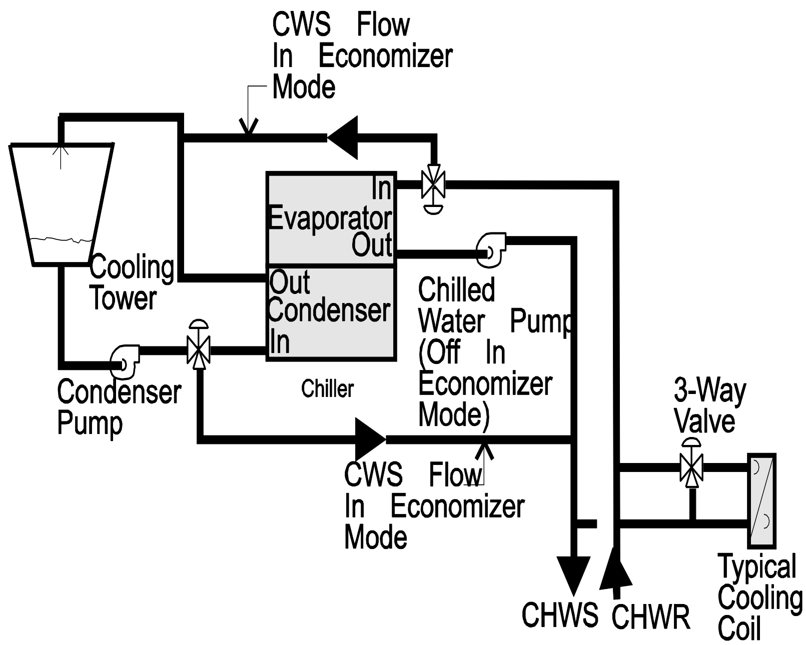
There are three common types of water-side economizers:

1. **Strainer-cycle or chiller-bypass water economizer** - The system depicted in Figure 4-36, below, does not meet the prescriptive requirement as it cannot operate in parallel with the chiller. This system is applied to equipment with chilled water coils.
2. **Water-precooling economizer** - The system depicted in

3. Figure 4-37 and Figure 4-36, below, meets the prescriptive requirement if properly sized. This system is applied to equipment with chilled water coils.
4. **Air-precooling water economizer** - The system depicted in Figure 4-39 below, also *meets* the prescriptive requirement if properly sized. The air-precooling water economizer is appropriate for water-source heat pumps and other water-cooled HVAC units.

To comply with the prescriptive requirements, the cooling tower serving a water-side economizer must be sized for all of the anticipated cooling load at the off-design outdoor-air condition of 50-degree F dry bulb/45-degree F wet bulb. This requires rerunning the cooling loads at this revised design condition and checking the selected tower to ensure that it has adequate capacity.

Figure 4-36: "Strainer-Cycle" Water Economizer



This system does not meet the prescriptive requirement as it cannot operate in parallel with the chiller

Figure 4-37: Water-Precooling Water Economizer with Three-Way Valves

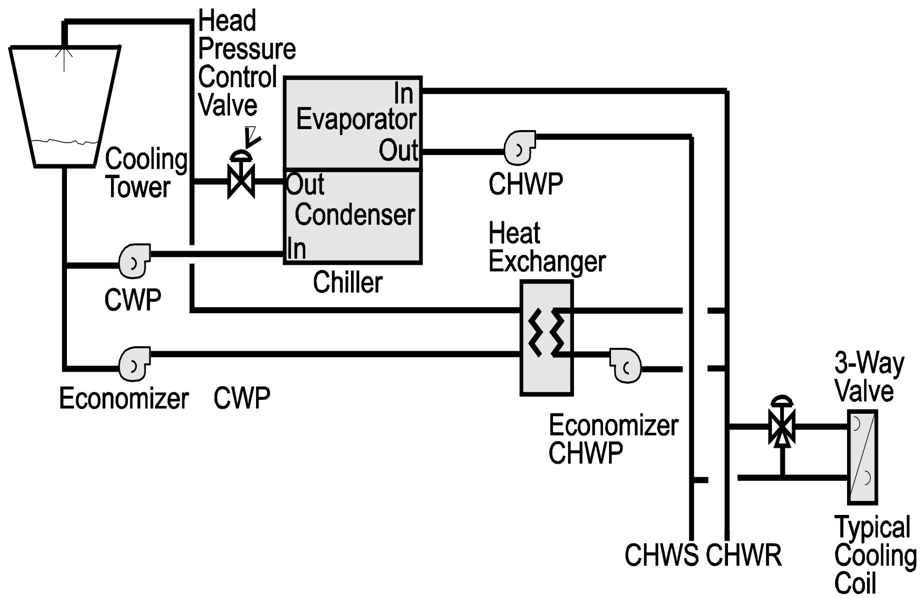


Figure 4-38: Water-Precooling Water Economizer with Two-Way Valves

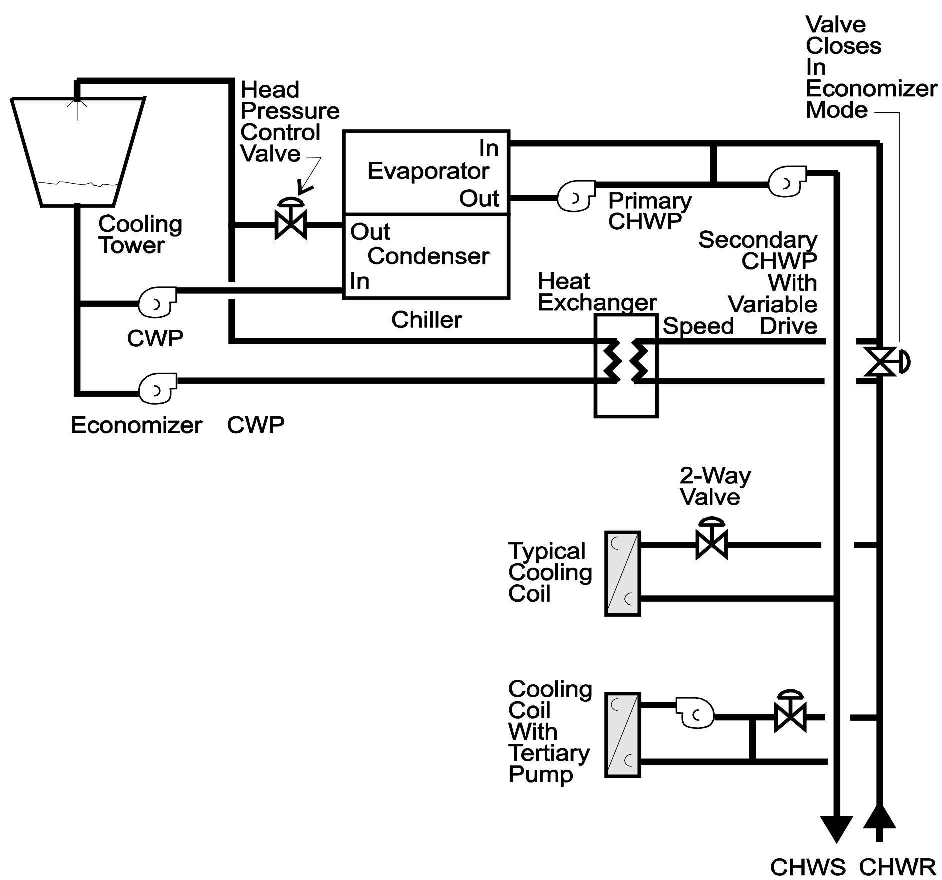
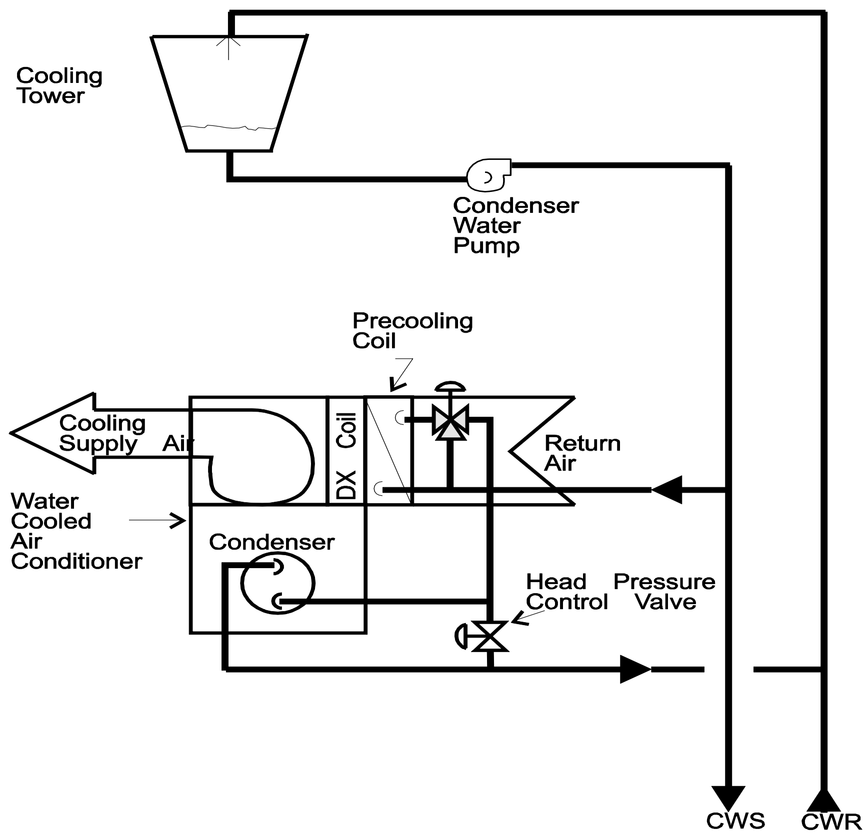


Figure 4-39: Air-Precooling Water Economizer



4.11.8 Unusual Sources of Contaminants

The regulation in §120.1 address ventilation requirements for buildings and uses the term of unusual sources of contamination. In this context, such contaminants are considered to be chemicals, materials, processes, or equipment that produce pollutants which are considered harmful to humans and are not typically found in most building spaces. Examples may include some cleaning products, blueprint machines, heavy concentrations of cigarette smoke and chemicals used in various processes.

The air classification is designated in Tables 4-12, 4-13, and 4-14. In addition, guidance for such spaces not listed is left to the designer's discretion, and may include considerations of toxicity, concentration, and duration of exposure. For example, while photocopiers and laser printers are known to emit ozone. If the equipment is scattered throughout a large space, it may not be of concern. A heavy concentration of such machines in a small space may merit special treatment, see Section 4.3).

4.11.9 Demand Controlled Ventilation (DCV)

DCV is required for use on systems that have an outdoor air economizer, and serve a space with a design occupant density (or maximum occupant load factor for egress purposes) greater than or equal to 25 people per 1000 sq ft (40 sq ft per person), according to §120.1(c)3. DCV is also allowed as an exception in the ventilation requirements for intermittently occupied systems, see §120.1(d)1. It is a concept in which the amount of outdoor air used to purge one or more offending pollutants from a building is a function of the measured level of the pollutant(s).

The regulation in §120.1 allows for DCV devices that employ a CO_2 sensor. CO_2 sensors measure the level of CO_2, which is used as a proxy for the amount of pollutant dilution in densely occupied spaces. CO_2 sensors have been on the market for many years and are available with integrated self-calibration devices that maintain a maximum guaranteed signal drift over a 5-year period.

DCV is available at either the system level (used to reset the minimum position on the outside air damper) and at the zone level (used to reset the minimum airflow to the zone). The zone level devices are sometimes integrated into the zone thermostat.

Occupant sensor ventilation control devises are required when the space needs to comply with the occupant sensor control requirements for lighting, see §130.1(c).

Some examples include:

- Offices smaller than 250 sq ft
- Multipurpose rooms smaller than 1,000 sq ft
- Classrooms, conference rooms, and restrooms of any size

4.11.10 Intermittently Occupied Spaces

The DCV devices discussed here are allowed and/or required only in spaces that are intermittently occupied. An intermittently occupied space is considered to be an area that is infrequently or irregularly occupied by people. Examples include auction rooms, movie theaters, auditoriums, gaming rooms, bars, restaurants, conference rooms and other assembly areas. Because the Energy Code requires base ventilation in office spaces that are very close to the actual required ventilation rate at 15 cfm per person, these controls may not save significant amounts of energy for these low-density applications. However, even in office applications, some building owners may install CO_2 sensors as a way to monitor ventilation conditions and alert to possible malfunctions in building air delivery systems.

4.12 Mechanical Plan Check and Inspection Documents

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the documents and recommended procedures documenting compliance with the mechanical requirements of the Energy Code. It does not describe the details of the requirements; these are presented in Section 4.2. The following discussion is addressed to the designer preparing construction documents and compliance documentation, and to the enforcement agency plan checkers who are examining those documents for compliance with the Energy Code.

The use of each document is briefly described. The information and format of these may be included in the equipment schedule:

NRCC-MCH-E: Certificate of Compliance

This dynamic document is required for every job, and it is required t on the plans. The following are included in the NRCC-MCH-E and only applicable forms will be required to be filled out.

- Major components of the heating and cooling systems, and service hot water and pool systems
- Outdoor air ventilation rates
- System fan power consumption

NRCC-PLB-E: Certificate of Compliance – Water Heating System General Information

This dynamic document is required for every job, and it is required t on the plans. The following are included in the NRCC-MCH-E and only applicable forms will be required to be filled out.

- All hot water systems
- Individual water heating systems installed in dwelling units in hotel / motels
- Central water heating systems that service multiple dwelling units installed in hotel/motels

4.12.1 Mechanical Inspection

The mechanical building inspection process for energy compliance is carried out along with the other building inspections performed by the enforcement agency. The inspector relies upon the plans and upon the NRCC-MCH-E Certificate of Compliance document printed on the plans.

4.12.2 Acceptance Requirements

Acceptance requirements can effectively improve code compliance and help determine whether mechanical equipment meets operational goals and whether it should be adjusted to increase efficiency and effectiveness.

For more detailed information on acceptance tests, see Chapter 13.

4.12.2.1 Acceptance Process

The process for meeting the acceptance requirements includes:

1. Document plans showing thermostat and sensor locations, control devices, control sequences and notes
2. Review the installation, perform acceptance tests document results
3. Document the operating and maintenance information, complete the certificate of installation and indicate test results on the certificate of acceptance, and submit the certificates to the enforcement agency prior to receiving a final occupancy permit.

4.12.2.2 Administration

The administrative requirements contained in the Energy Code requires the following:

1. Requirements for acceptance testing of mechanical systems and equipment shown in the table below are included in the plans and specifications:

Table 4-15: Mechanical Acceptance Tests

Variable Air Volume Systems
Constant Volume Systems
Package Systems
Air Distribution Systems
Economizers
Demand Control Ventilation Systems
Ventilation Systems
Variable Frequency Drive Fan Systems
Hydronic Control Systems
Hydronic Pump Isolation Controls and Devices
Supply Water Reset Controls
Water Loop Heat Pump Control
Variable Frequency Drive Pump Systems

2. Within 90 days of receiving a final occupancy permit, record drawings be provided to the building owners

3. Operating and maintenance information be provided to the building owner
4. The issuance of installation certificates for mechanical equipment

For example, the plans and specifications would require an economizer. A construction inspection would verify the economizer is installed and properly wired. Acceptance tests would verify economizer operation and proper function the relief air. Owners' manuals and maintenance information would be prepared for delivery to the building owner. Finally, record drawing information-including economizer controller set points-must be submitted to the building owner within 90 days of the issuance of a final occupancy permit.

4.12.2.3 Plan Review

Although acceptance testing does not require that the construction team perform any plan review, they should review the construction drawings and specifications to understand the scope of the acceptance tests and raise critical issues that might affect the success of the acceptance tests prior to starting construction. Any construction issues associated with the mechanical system should be forwarded to the design team so that necessary modifications can be made prior to equipment procurement and installation.

4.12.2.4 Testing

The construction inspection is the first step in performing the acceptance tests. In general, this inspection should identify that:

1. Mechanical equipment and devices are properly located, identified, and calibrated.
2. Set points and schedules are established.
3. Documentation is available to identify settings and programs for each device.
4. Select tests to verify acceptable leakage rates for air distribution systems while equipment access is available. Testing is to be performed on the following devices:
   - VAV systems
   - Constant volume systems
   - Package systems
   - Air distribution systems
   - Economizers
   - Demand control ventilation systems
   - Variable frequency drive fan systems
   - Hydronic control systems
   - Hydronic pump isolation controls and devices

- Supply water reset controls
- Water loop heat pump control
- Variable frequency drive pump systems
- System programming
- Time clocks

Chapter 13 contains information on how to complete the acceptance documents. Example test procedures are also available in Chapter 13.

4.12.2.5 Roles and Responsibilities

The installing contractor, engineer of record or owner’s agent shall be responsible for documenting the results of the acceptance test requirement procedures including paper and electronic copies of all measurement and monitoring results. They shall be responsible for performing data analysis, calculation of performance indices and crosschecking results with the requirements of the Energy Code. They shall be responsible for issuing a Certificate of Acceptance. Enforcement agencies shall not release a final Certificate of Occupancy until a Certificate of Acceptance is submitted that demonstrates that the specified systems and equipment have been shown to be performing in accordance with the Energy Code. The installing contractor, engineer of record or owner’s agent (upon completion of all required acceptance procedures) shall record their State of California contractor’s license number or their State of California professional registration license number on each certificate of acceptance that they issue.

4.12.2.6 Contract Changes

The acceptance testing process may require the design team to be involved in project construction inspection and testing. Although acceptance test procedures do not require that a contractor be involved with a constructability review during design-phase, this task may be included on individual projects at the owner’s request. Therefore, design professionals and contractors should review the contract provided by the owner to make sure it covers the scope of the acceptance testing procedures as well as any additional tasks.

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Table of Contents

5 Nonresidential Indoor Lighting

This chapter covers the Energy Code requirements for indoor lighting design, installation, and controls for conditioned and unconditioned nonresidential buildings.

Chapter 6 addresses nonresidential outdoor lighting requirements.

Chapter 7 addresses sign lighting requirements.

5.1 Overview

The Energy Code requires that total lighting power is within a specified budget, and that lighting controls are installed for efficient operation of installed lighting.

5.1.1 What's New for the 2022 Energy Code?

Significant changes for indoor lighting systems in the 2022 update to the Energy Code include:

- Mandatory occupant sensing controls for office spaces greater than 250 square feet.
- Requirements for high-rise residential buildings that are moved to new multifamily chapters in the Energy Code.
- Automatic daylighting controls that must reduce controlled lighting power to 10 percent or less when adequate daylighting is available in a space.
- Automatic daylighting controls for secondary sidelit daylit zones becoming a mandatory requirement (previously prescriptive).
- Updates to the power adjustment factors in Table 140.6-A for daylight continuous dimming plus OFF controls, occupant sensing controls in offices larger than 250 sq. ft., and demand-responsive lighting controls.
- Lighting power allowances in the Area Category Method that have been combined for greater flexibility.
- Updates to lighting power density allowances in Table 140.6-B for the Complete Building Method.
- Updates to lighting power density allowances in Table 140.6-C for the Area Category Method.
- Updates to lighting power density allowances in Table 140.6-D and Table 140.6-G for the Tailored Method.
- Additional testing method for partial daylighting acceptance testing.

5.1.2 Scope

The nonresidential indoor lighting requirements are contained in §100.0, §110.9, §110.12, §120.8, §130.0, §130.1, §130.4, §140.0, §140.1, §140.3, §140.6, and §141.0 of the Energy Code. Supporting definitions are in §100.1.

- The nonresidential indoor lighting requirements apply to nonresidential buildings and hotel/motel occupancies (including guest rooms). Hotel/motel guest rooms are covered by portions of both the nonresidential indoor lighting requirements and the residential indoor lighting requirements. (See Chapter 6 of the 2022 Residential Compliance Manual.)
- Lighting requirements for multifamily buildings are covered in Chapter 11. Chapter 11 also covers multifamily buildings and residential spaces in mixed-use buildings.
- The nonresidential indoor lighting requirements are the same for conditioned and unconditioned spaces. Lighting power trade-offs are not allowed between conditioned and unconditioned spaces.
- Qualified historical buildings are regulated by the California Historical Building Code, not the Energy Code. However, nonhistorical components of such buildings may need to comply with the Energy Code. For more information, see Section 1.7.2.

All section and table references in this chapter refer to sections and tables contained in the Energy Code.

Refer to Chapter 6 of the Residential Compliance Manual Chapter 6 for information on lighting requirements for single-family residential buildings.

5.1.3 Functional Areas in Nonresidential Buildings That Must Comply With Applicable Residential Requirements

The following functional areas in nonresidential and hotel/motel occupancies are required to comply with the applicable residential lighting requirements in §150.0(k):

- Fire station dwelling accommodations
- Hotel and motel guest rooms

  Note that hotel and motel guest rooms are required to comply with §130.1(c)8, which requires captive card key controls, occupant sensing controls, or automatic controls. In addition, hotel and motel guest rooms are required to meet the controlled receptacle requirements of §130.5(d)4.

  EXCEPTION: One luminaire in a hotel or motel guest room that meets the following criteria is exempt from the control requirement:

  - The luminaire is classified as high efficacy (as defined in §150.0[k] and Table 150.0-A).
  - The luminaire is switched separately from the other lighting in the room.
  - The switch for the luminaire is located within 6 feet of the entry door.
- Outdoor lighting attached to a hotel/motel building and separately controlled from inside a guest room.

Note that the above requirements also apply to additions and alterations to functional areas of existing buildings specified above.

5.1.4 Indoor Lighting Power Allotments Overview

Lighting power allotments are the established maximum lighting power that can be installed based on the compliance approach used, the building type, and building area. Lighting power allotments for an application are determined by one of the following four compliance approaches:

A. Prescriptive Approach – Complete Building Method

Applicable when the lighting system of an entire building is designed and permitted at one time and when at least 90 percent of the building is one nonresidential building occupancy type (as defined in §100.1). This method may also be used for a tenant space in a multitenant building if at least 90 percent of the tenant space is one building occupancy type. A single lighting power density value governs the entire building or tenant space.

B. Prescriptive Approach – Area Category Method

Applicable for any permit situation including tenant improvements. Lighting power density values are assigned to each of the primary function areas of a building (offices, lobbies, corridors, etc.) as defined in §100.1. This approach allows some flexibility to accommodate special task lighting needs by providing an additional power allowance under some circumstances.

C. Prescriptive approach – Tailored Method

Applicable for a limited number of defined primary function areas when additional flexibility is needed to accommodate special task lighting needs. Several layers of lighting power allotments may be allowed depending on the space and tasks. Lighting power allotments are determined room-by-room and task-by-task. Some areas in a building may use the Tailored Method while others use the Area Category Method.

D. Performance Approach

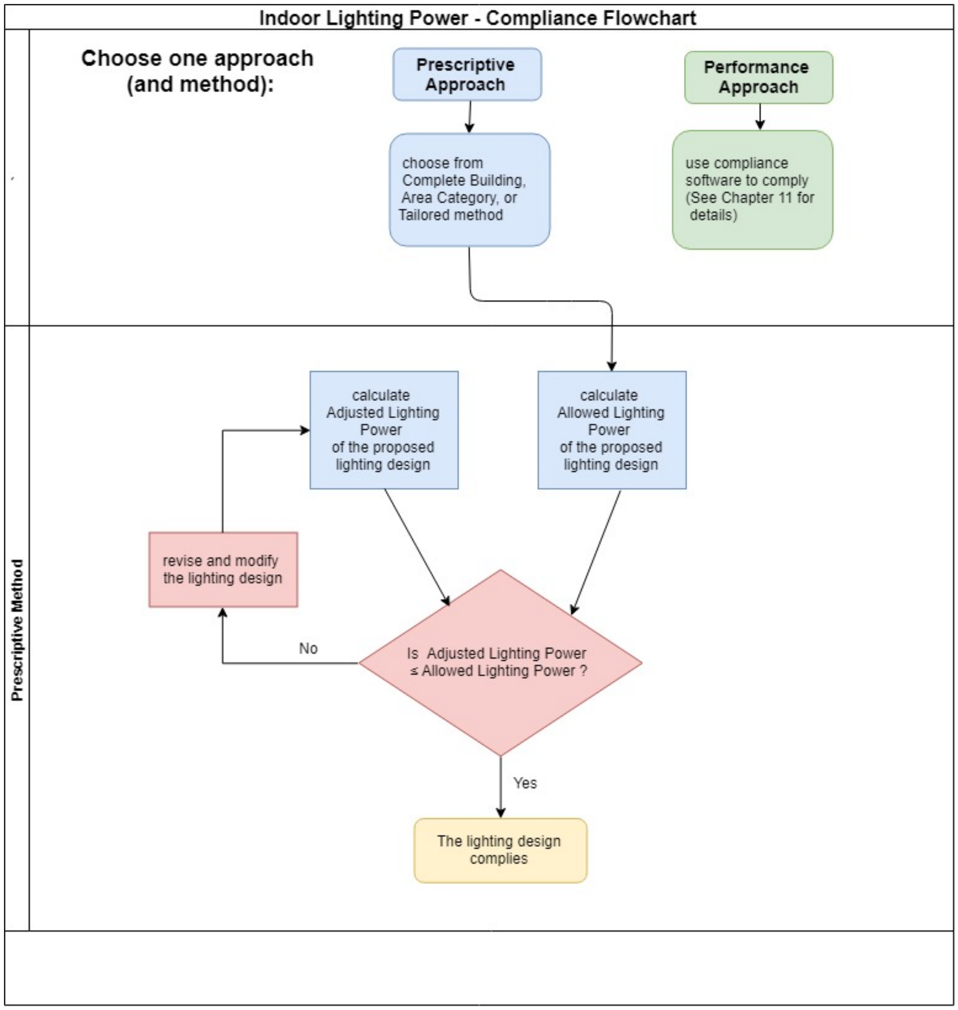
Applicable when the designer uses an California Energy Commission-certified compliance software program to demonstrate that the energy consumption of the proposed building (including indoor lighting power) meets the energy budget. The performance approach incorporates one or more of the three previous methods, which establishes the custom energy budget of the building.

The performance approach allows energy allotments to be traded among space conditioning, mechanical ventilation, indoor lighting, service water heating, envelope, and covered process loads. Such trade-offs can be made only when permit applications are sought for those systems involved. For example, under the performance approach, a building with an envelope or mechanical ventilation system that is more efficient than the prescriptive efficiency requirements, may be able to meet the energy budget with more lighting power than allowed under the three prescriptive lighting approaches.

No additional lighting power allotment is gained by using the performance method unless it is traded from the space conditioning, mechanical ventilation, service water heating, envelope, or covered process systems. Therefore, the performance approach is not applicable to lighting compliance alone. The performance approach may be used only to model the performance of indoor lighting systems that are covered under the building permit application.

Figure 5-1 shows the process for complying with the nonresidential indoor lighting requirements.

Table 5-1: Indoor Lighting Power Compliance Overview Flowchart



Source: California Energy Commission

E. Choose an Indoor Lighting Power Compliance Approach (Refer to the Top Part of Figure 5-1):

First, select either the prescriptive or performance approach for complying with the nonresidential indoor lighting power requirements of the Energy Code.

For the performance approach, lighting power calculations can be performed using an approved software program. Refer to the compliance software documentation for details.

For the prescriptive approach, choose from among the Complete Building Method, the Area Category Method, or the Tailored Method.

Calculate the "allowed" lighting power using the chosen method. Allowed lighting power is the maximum lighting wattage that may be installed for the project (using lighting power values from Table 140.6-B, C, and D).

Next, calculate the "adjusted" lighting power. Adjusted lighting power is designed lighting power *minus* lighting control credits *minus* lighting power reduction.

F. Evaluate the Calculations — Allowed Lighting Power vs. Adjusted Lighting Power

If the adjusted lighting power is less than or equal to the allowed lighting power, the proposed lighting complies with the Energy Code.

If the adjusted lighting power is greater than the allowed lighting power, the proposed lighting does not comply with the Energy Code. To comply, the proposed lighting power must be reduced by redesigning the lighting system, or, if using the performance approach, additional lighting credits may be acquired through improved efficiency in other systems.

5.1.5 Compliance Process — Forms, Plan Check, Inspection, Installation, and Acceptance Tests

The compliance process begins with the builder submitting certificates of compliance to the responsible code enforcement agency. The certificates provide all design information necessary to show that the proposed project will comply with the Energy Code. Construction may not begin until all certificates of compliance are reviewed and approved by the enforcement agency.

As construction proceeds, builders must submit certificates of installation certifying that installed equipment and systems meet or exceed the design criteria specified in the approved certificates of compliance. Code enforcement officials may conduct field inspections to verify information submitted by builders. At the end of construction, acceptance tests must be performed by qualified contractors on all specified systems to ensure they are installed correctly and function per code requirements.

If inspections or acceptance tests identify noncompliant or nonfunctional systems, these defects must be fixed. Once the enforcement agency determines the project complies with all building code requirements, including the Energy Code, the building will receive a certificate of occupancy that certifies that the building complies with the building code.

5.2 General Requirements

Some requirements in the Energy Code are classified as "mandatory requirements" because they are required regardless of the compliance approach used. All projects must comply with all mandatory requirements.

It is the responsibility of the designer to design a lighting system and specify products that meet these requirements. It is the responsibility of the installer to install the lighting and controls specified on the plans. It is the responsibility of code enforcement officials to verify that the mandatory requirements are included on the plans and installed in the field.

The mandatory requirements for nonresidential indoor lighting include the following:

- Certain functional areas in nonresidential buildings must comply with the low-rise residential lighting requirements in §130.0(b).
- Manufactured lighting equipment, products, and devices must be appropriately certified or meet functionality requirements in §110.0(b), §110.1, and §110.9(a).
- Requirements for how luminaires shall be classified (according to technology) and how luminaire power shall be determined in §130.0(c).
- Required indoor lighting controls in §130.1.
- Lighting control acceptance testing in §130.4(a).
- Lighting control certificates of installation in §130.4(b).

The Energy Code also includes mandatory requirements for electrical power distribution systems. See Chapter 8 for more information.

5.3 Luminaire Classification and Lighting Terms

§130.0(c)

Luminaires and light sources emit light and illuminate spaces. The Energy Code include a system of classification to account for the power of luminaires and lighting systems and use the information for assessing compliance.

Below is the list of luminaire types described and classified in §130.0(c):

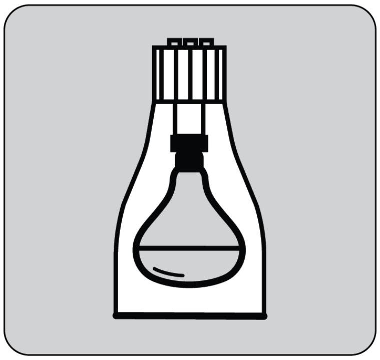
- Luminaires with line-voltage lamp holders
- Luminaires with ballasts
- Inseparable solid-state lighting (SSL) luminaires and SSL luminaires with remote drivers
- LED tape lighting and LED linear lighting
- Modular lighting systems
- Other lighting equipment

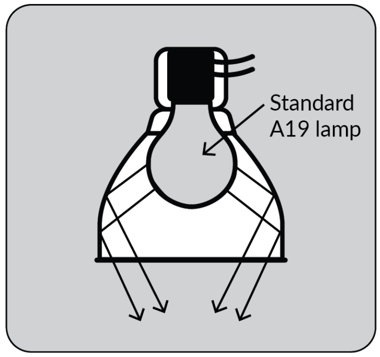
The wattage of all planned lighting systems, including permanent and portable lighting, shall be determined as follows.

5.3.1 Luminaires With Line-Voltage Lamp Holders

The wattage of luminaires with line-voltage lamp holders not served by drivers, ballasts, or transformers shall be the maximum-rated wattage of the luminaire.

Figure 5-1: Examples of Luminaires With Line-Voltage Lamp Holders





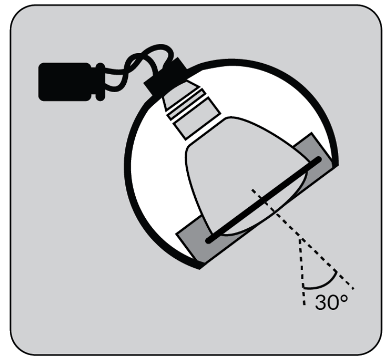


Image Source: Energy Solutions

5.3.2 Luminaires With Ballasts

The wattage of luminaires with permanently installed or remotely installed ballasts shall be the operating input wattage of the rated lamp/ballast combination.

This wattage information can be found in the ballast manufacturer's catalogs based on an independent testing lab report as specified in UL 1598.

5.3.3 Inseparable SSL Luminaires and SSL Luminaires With Remotely Mounted Drivers

The wattage of inseparable SSL luminaires and SSL luminaires with remote ballasts shall be the maximum-rated input wattage of the SSL luminaire.

Inseparable SSL luminaires are luminaires manufactured with solid-state lighting components that are not readily removed or replaced from the luminaires by the end users.

SSL luminaires shall be tested in accordance with UL 1598, 2108, or 8750, or IES LM-79.

Figure 5-2: Examples of SSL Luminaires: Recessed Downlight Luminaires

Image Source: Lutron Electronics Co., Inc.

5.3.4 LED Tape Lighting and LED Linear Lighting

LED tape lighting can be installed in varying lengths by installers on a project site as determined by the lighting design requirements. LED tape lighting is not like luminaires, which are manufactured in predetermined dimensions per customer order.

The wattage of LED tape lighting and LED linear lighting with LED tape lighting components shall be the sum of the installed length of the tape lighting times its rated linear power density in W/ft or the maximum-rated input wattage of the driver or power supply providing power to the lighting system.

Tape lighting shall be tested in accordance with UL 2108 or 8750, or IES LM-79.

Figure 5-3 Examples of LED Tape Lighting

Source: NORA Lighting

5.3.5 Modular Lighting Systems

Track-mounted and rail-mounted luminaires that allow the addition or relocation of luminaires without altering the wiring are examples of modular lighting systems. The wattage of these systems shall be determined as follows:

- The wattage shall be the greater of 30 watts per linear foot of track or plug-in busway or the rated wattage of all of the luminaires in the system (where the luminaire wattage is as specified by UL 1574, 1598, 2108, or 8750).
- For line-voltage track lighting and plug-in busway served by a track lighting current limiter, the wattage shall be the volt-ampere rating of the current limiter as specified by UL 1077.
- For line-voltage track lighting and plug-in busway served by a track lighting protection panel, the wattage shall be the sum of the ampere ratings of all the overcurrent protection devices times the branch circuit voltage for the track lighting protection panel.
- For other modular systems with power supplied by a driver, power supply, or transformer, including low-voltage lighting systems, the wattage shall be the maximum rated input wattage of the driver, power supply, or transformer as specified by UL 2108 or 8750.

- For power-over-Ethernet lighting systems, the wattage shall be the total power rating of the system less any installed nonlighting devices.

Figure 5-4 A Track Lighting System (top image); A Track Lighting Installation (bottom image)

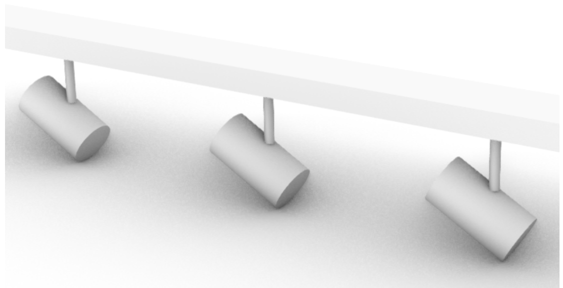


Image Source: California Energy Commission

Image Source: Acuity Brands Lighting, Inc.

5.3.6 Other Lighting Equipment

For lighting equipment not addressed above, the wattage of the lighting equipment shall be the maximum-rated wattage of the lighting equipment or the operating input wattage of the system, based on independent test lab reports as specified by UL-1547, 1598, 2108, or 8750, or IES LM-79.

Example 5-1 Power-Over-Ethernet Lighting

Question

What is a power-over-Ethernet (PoE) lighting system?

Answer

A PoE lighting system provides low-voltage direct current and communication over Ethernet cabling. By contrast, most conventional lighting systems use alternating current to power luminaires.

A PoE lighting system usually contains three main components — a powered device (PD), Ethernet cabling, and power sourcing equipment (PSE) such as Ethernet switches. PSE is a general term used for a PoE power supply.

PSEs supply power via Ethernet cabling to PDs, such as PoE luminaires.

Example 5-2 PoE Lighting

Question

What is the wattage of a PoE lighting system that contains a PoE switch, nine PoE luminaires, occupancy sensors, one daylight sensor, and wall switch stations?

Answer

One way to determine the answer is to account for the wattage of all the luminaires in the lighting system as the wattage of the PoE lighting system. Since there are nine PoE luminaires plus other nonlighting loads (sensors and switches), the wattage of the PoE lighting system is the sum of the wattage of all PoE luminaires, excluding the sensors and control switches.

Another way is to account for the total power rating of the system less any nonlighting devices such as occupancy sensors, sensing devices, and switch controls.

5.3.7 Lighting Terms

The following is a selection of lighting terms defined in §100.1 and included here to help readers understand the requirements.

A. General Lighting

General lighting (also known as ambient lighting) is electric lighting that provides a uniform level of illumination throughout an area exclusive of any provision for special visual tasks or decorative effect, or exclusive of daylighting.

Typical luminaires used for general lighting are troffers (prismatic, parabolic, or indirect diffusers), pendants (direct, indirect, or direct/indirect), high bay, low bay, and “aisle-lighter” fixtures. General lighting does not include display lighting (typically using directional MR, PAR, flood, spot, or wall washers) or decorative lighting (such as drum fixtures, chandeliers, or projection lighting.)

B. Decorative, Display, Task, and Special Effects Lighting

Section 100.1 also defines decorative, display, task, and special effects lighting as follows:

- Decorative lighting or luminaires are installed only for aesthetic purposes that do not serve as display lighting or general lighting. Decorative luminaires are chandeliers, sconces, lanterns, cove lighting, neon or cold cathode, theatrical projectors, moving lights, and light color panels, not providing general lighting or task lighting.
- *Display lighting* is supplementary lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance required to highlight features, such as merchandise, sculpture, or artwork.
- *Task lighting* is lighting directed to a specific surface or area providing illumination for visual tasks. Task lighting is not general lighting.
- *Special effects lighting* is lighting installed to give off luminance instead of providing illuminance, which does not serve as general, task, or display lighting.

Special effects lighting is different from decorative lighting. The only place special effects lighting is used is for the Decorative/Special Effects Lighting additional power allowance in the tailored method for lighting power compliance in Table 140.6-D where both terms are combined.

Both the Area Category Method (Table 140.6-C) and the Tailored Method (Table 140.6-D) provide additional lighting power allowances for lighting that is not considered general lighting; however, to claim these allowances, the nongeneral lighting systems must be separately switched.

For layered lighting designs with multiple luminaire types, compliance documentation will require allocating some or all nongeneral lighting power to the additional lighting power allowances and the rest of the lighting wattage to the general lighting power allowance. Only the general lighting power allowance is able to be shared across different spaces.

When there is only one lighting system type in a space, such as is the case when a monolithic design approach is taken, that system type will be treated as general lighting. Thus, light fixtures that might ordinarily be considered decorative or display luminaires are considered general lighting luminaires if they are the only system type in a given enclosed space.

Example 5-3 LED Tape Lighting

LED tape lighting may be classified as Decorative Lighting, Task Lighting, or General Lighting, based on how it is used. Figure 5-5 shows two applications of LED tape lighting.

The image G3-A on the left shows LED tape lighting that is installed in a channel mounted to the underside of a shelf or cabinet or installed directly with adhesive material. This use would be classified as display or task lighting. Such applications are not considered General Lighting.

The image G3-B on the right shows an architectural cove with tape lighting installed in a channel mounted within the cove or installed directly with adhesive material. This use may be classified as Decorative or Display Lighting or considered General Lighting, based on whether the illumination emanating from the cove is the only source of uniform lighting in the space.

Figure 5-5 Examples of LED Tape Lighting: In Use as Undershelf Lighting (left image); In Use as Cove Lighting (right image)

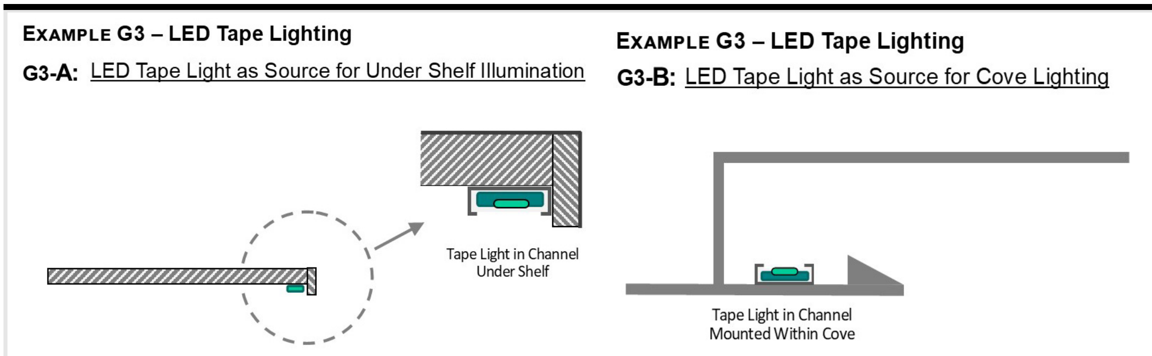


Image Source: Bernie Bauer

Example 5-4: Cove Lighting

Room A & Room B have two lighting systems: The first system consists of linear luminaires mounted in a cove to provide up-lighting bouncing off the ceiling and providing general illumination. The other system is a series of downlights providing task illumination over an alcove in the room. Cove lighting may be classified as decorative or display lighting when there are other luminaires providing general illumination. However, the cove lighting in this example also provides general illumination. Therefore, the cove lighting luminaire power is applied to the allowed general lighting LPD shown in Table 140.6-C Area Category Method or Table 140.6-D Tailored Method instead of as a decorative or display allowance from Table 140.6-C or 140.6-D. The lighting power of the downlights providing task illumination are assigned to Additional Lighting Power in Table 140.6-C or Allowed Task Lighting Power in Table 140.6-D, provided they are on a separate circuit. If they are on the same circuit as the cove lights, they must also be included in the base lighting allowance.

Room C has three lighting systems:

1) Asymmetric distribution luminaires mounted in a cove to provide up-lighting bouncing off the ceiling for visual enhancement.
2) A grid of flood downlights designed to provide general illumination.
3) A series of downlights providing task illumination over two alcoves in the room. Cove lighting in this scenario may be classified as decorative or display lighting

and can use the decorative/display allowances shown in Table 140.6-C or the decorative/special effects allowance in Table 140.6-D, provided one is available for the space type in which the cove is located, and the cove is separately circuited from the downlights. The flood downlights are designed to provide general/ambient illumination; therefore, the general lighting LPD allowances in Table 140.6-C or 140.6-D apply. As with the cove lights, the downlights providing task illumination can use the appropriate additional allowances in Table 140.6-C or 140.6-D, provided one is available and they are separately circuited.

Figure 5-6 Examples of Cove Lighting: Asymmetric Distribution Luminaires in Cove (Room C); Linear Luminaires in Cove (Rooms A and B)

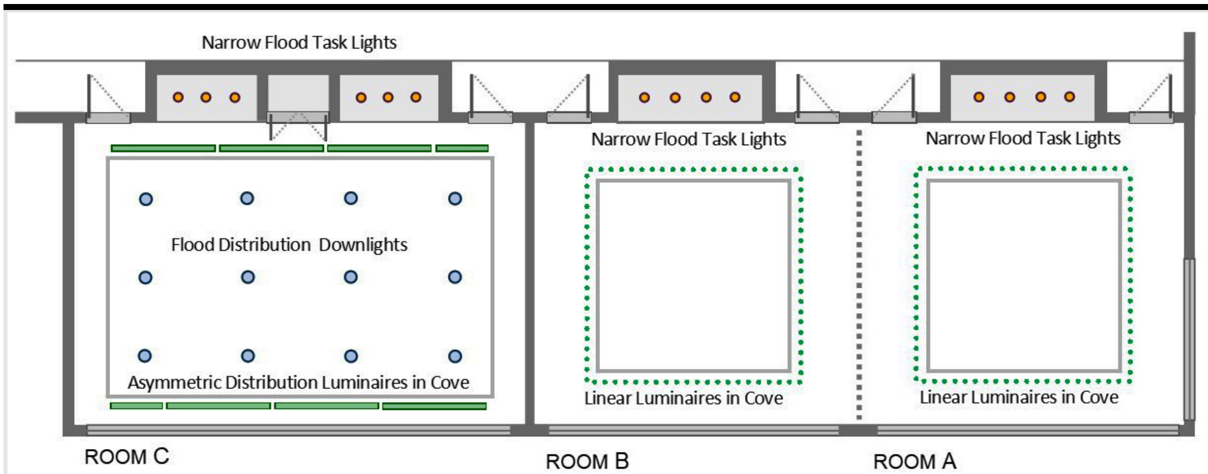


Image Source: Bernie Bauer

5.4 Mandatory Lighting Controls

§130.1

This section contains information about lighting controls that must be installed regardless of the method used to comply with the lighting power requirements**.**

All lighting controls and equipment must comply with the applicable requirements in §110.9, 130.1, 130.2, and must be installed in accordance with the manufacturer's instructions (§130.0(d)).

Mandatory nonresidential indoor lighting controls include the following:

1. Manual area controls, allowing on and off control for each area separately.
2. Multilevel controls, allowing the ability to use all, some, or none of the light in an area.

3. Shut-off controls, which, automatically shut off or reduce light output when a space is vacant.
4. Automatic daylighting controls, which separately control general lighting in the daylit area based on the amount of daylight in the space.
5. Demand-responsive lighting controls, which are capable of receiving and automatically responding to a demand response signal.

5.4.1 Manual Area Controls

§130.1(a) of Part 6; §10-103(a)2 of Part 1

Each building area shall provide lighting controls that allow lighting in that area to be manually turned on and off. Manual area controls allow building occupants to control the light while they are in the space.

The manual area controls shall meet the following requirements:

1. Be readily accessible.

   EXCEPTION: Restrooms having two or more stalls, parking areas, stairwells, corridors, and areas of the building intended for access or use by the public may use a manual control not accessible to unauthorized personnel.

2. Be located in the same enclosed area with the lighting it controls.

   EXCEPTION 1: For malls and atria, main entry lobbies, auditorium areas, dining areas, retail merchandise sales areas, wholesale showroom areas, commercial and industrial storage areas, general commercial and industrial work areas, convention centers, arenas, psychiatric and secure areas in healthcare facilities, and other areas where placement of a manual area control poses a health and safety hazard, the manual area control shall instead be located so that a person using the control can see the lights or area controlled by that control, or visually signal or display showing the current state of the controlled lighting.

   EXCEPTION 2: Healthcare facility restrooms and bathing rooms intended for a single occupant can have lighting controls located outside the enclosed area but directly adjacent to the door.

3. Separately control general, floor display, wall display, window display, case display, decorative, and special effects lighting such that each type of lighting can be turned on and off without turning on or off other types of lighting or other equipment. Scene controllers may comply with this requirement provided that at least one scene turns on general lighting only, and the control provides a means to manually turn off all lighting.

For egress lighting required by the California Building Code, up to 0.1 W/sq. ft. of indoor lighting may be continuously illuminated during occupancy. Egress lighting that complies with this wattage limitation is not required to comply with manual area control requirements if:

1. The means of egress area is shown on the building plans and specifications submitted to the local enforcement agency under Section 10-103(a)2 of Part 1 (California Code of Regulations Title 24).
2. The egress lighting controls are inaccessible to unauthorized personnel.

5.4.2 Multilevel Lighting Controls

§130.1(b) & Table 130.1-A

Multilevel lighting controls allow the lighting level to be adjusted to accommodate how a room is being used.

This requirement applies to general lighting in enclosed spaces 100 sq. ft. or larger with a connected general lighting load greater than 0.5 W/sq. ft. General lighting does not include task, display, or decorative lighting.

The multilevel control must meet the minimum required control steps and uniformity requirements in Table 130.1-A. The minimum required control steps are determined by the type of light source or luminaire being controlled.

For some light sources and luminaires, dimming can be implemented in steps or over a continuous range. Continuous dimming provides a smoother transition of light levels compared to stepped dimming.

Classrooms with a connected general lighting load of 0.6 W/sq. ft. or less shall have a minimum of one control step between 30 percent and 70 percent of full rated power, regardless of luminaire type.

EXCEPTION: The following applications are not required to comply with the multilevel lighting control requirements:

1. An area enclosed by ceiling height partitions with only one luminaire containing no more than two lamps or with only one inseparable SSL luminaire
2. Restrooms
3. Healthcare facilities

Table 5-2 (From Table 130.1-A): Multilevel Lighting Controls and Uniformity Requirements

Luminaire Type	Minimum Required Control Steps (percent of full rated power1)	Uniform level of illuminance shall be achieved by:
LED luminaires and LED light sources	Continuous dimming 10-100%	Continuous dimming 10-100%
Line-voltage sockets except GU-24	Continuous dimming 10-100%	Continuous dimming 10-100%
Low-voltage incandescent systems	Continuous dimming 10-100%	Continuous dimming 10-100%
Fluorescent luminaires	Continuous dimming 20-100%	Continuous dimming 20-100%
GU-24 sockets rated for fluorescent ≤ 20 watts Pin-based compact fluorescent ≤ 20 watts2 Linear fluorescent and U-bent fluorescent ≤ 13 watts	Minimum one step between 30-70%	Continuous dimming or Stepped dimming or Switching alternate lamps in a luminaire or Separately switching circuits in multicircuit track with a minimum of two circuits.
Track Lighting	Minimum one step between 30 – 70%	Continuous dimming or Stepped dimming or Separately switching circuits in multicircuit track with a minimum of two circuits.
Linear Fluorescent and U-bent fluorescent > 13 watts	Minimum one step in each range: 20 – 40% 50 – 70% 75 – 85% 100%	Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 4 lamps per luminaire, illuminating the same area in the same manner.
Other light sources, including HID and Induction	Minimum one step between 50 – 70%	Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner.

1. Full rated input power of driver, ballast, and lamp, corresponding to maximum ballast factor.
2. Includes only pin-based twin tube, multiple twin tube, and spiral lamps.

5.4.3 Shut-Off Controls

§130.1(c)

All installed indoor lighting shall be equipped with controls that are able to automatically reduce lighting power when the space is typically unoccupied.

EXCEPTION: Healthcare facilities are not required to meet the shut off control requirements.

Shut off controls can be used to automatically turn off or reduce lighting when the spaces are not occupied. For example, an office building is typically unoccupied at night and on weekends; automatic shutoff controls ensure that lighting is off during these periods.

In addition to lighting controls installed to comply with §130.1(a) (manual on and off controls located in each area) and §130.1(b) (multilevel lighting controls) , all installed indoor lighting shall be equipped with shut off controls that meet the following requirements (§130.1[c]1):

1. One or more of the following automatic shut off controls:
   - Occupant sensing control
   - Automatic time-switch control
   - Other control capable of automatically shutting off all lighting when the space is typically unoccupied
2. Separate controls for lighting on each floor, other than lighting in stairwells
3. Separate controls for a space 5,000 square feet or smaller enclosed by ceiling-height partitions. Spaces larger than 5,000 square feet will have more than one separately controlled zone (where each zone does not exceed 5,000 square feet)

   EXCEPTION: The area controlled may not exceed 20,000 square feet in the following function areas: malls, auditoriums, single-tenant retail, industrial, convention centers, and arenas

The following applications are exempt from the shut off control requirements of §130.1(c)1:

- An area that is in 24-hour use every day of the year.
- Lighting complying with the occupant sensing control requirements of §130.1(c)5 instead of §130.1(c)1.
  - This exception applies to those areas where occupant sensing controls are required to shut off all lighting. These areas include offices 250 sq. ft. or smaller, multipurpose rooms of less than 1,000 sq. ft., classrooms of any size, conference rooms of any size, or restrooms of any size.

- Lighting complying with the partial- off occupant sensing control requirements of §130.1(c)7 instead of §130.1(c)1.
    - This exception applies to those areas where partial off occupant sensing controls are required. These areas include stairwells and common area corridors that provide access to guestrooms and dwelling units in accordance with §130.1(c)7A, or parking garages, parking areas, and loading and unloading areas in accordance with §130.1(c)7B.
- Lighting up to 0.1 watts per sq. ft. may be continuously illuminated for egress illumination. Lighting providing "egress illumination," as used in the California Building Code, shall provide no less light than required by California Building Code Section 1008 while in the partial-off mode.
- Electrical equipment rooms covered by Article 110.26(D) of the California Electrical Code.
- Lighting that is designated as emergency lighting that is connected to an emergency power source or battery supply and intended to function in emergency mode only when normal power is absent.

5.4.3.1 Use of Countdown Timer Switches

Countdown timer switches may be used to comply with the automatic shut off control requirements in §130.1(c)1 only in closets smaller than 70 sq. ft. and server aisles in server rooms.

The maximum timer setting shall be 10 minutes for closets and 30 minutes for server aisles.

5.4.3.2 Automatic Time-Switch Controls With Manual Override

Automatic time-switch controls other than an occupant sensing control shall include a manual override control that complies with §130.1(a) and allows the lighting to remain on for no more than two hours when an override is initiated.

EXCEPTIONS: In the following functional areas, the override time may exceed two hours if a captive-key override is used:

- Malls
- Auditoriums
- Single-tenant retail
- Industrial
- Laboratories
- Arenas

5.4.3.3 Automatic Time-Switch Control Holiday Shut Off Feature

An automatic holiday shut off feature shall be incorporated with the automatic time-switch control that turns off all loads for at least 24 hours, and then resumes the normally scheduled operation.

EXCEPTIONS: The following are not required to incorporate the holiday shut off feature:

- Retail stores and associated malls
- Restaurants
- Grocery stores
- Churches
- Theaters

5.4.3.4 Areas Where Occupant Sensing Controls are Required to Shut Off All Lighting After Occupancy

§130.1(c)5

Lighting in the following areas shall be controlled with occupant sensing controls to automatically shut off all of the lighting in 20 minutes or less after the control zone is unoccupied. In addition, controls shall be provided that allow the lights to be manually shut off in accordance with §130.1(a) regardless of the sensor status:

a. Offices 250 sq. ft. or smaller
b. Multipurpose rooms smaller than 1,000 sq. ft.
c. Classrooms of any size
d. Conference rooms of any size
e. Restrooms of any size

In areas required by §130.1(b) to have multilevel lighting controls, the occupant sensing controls shall function as one of the following:

a. A partial-on occupant-sensing control capable of automatically activating between 50 and 70 percent of controlled lighting power (requires lights to be turned ON manually to 100 percent) and automatically turning lights off when the space is unoccupied
b. A vacancy-sensing control that automatically turns lights off after an area is vacated and requires lights to be turned on manually

For areas not required by §130.1(b) to have multilevel lighting controls, occupant sensing controls may function as one of the following:

a. A normal occupant-sensing control with automatic on and off functionality
b. A partial-on occupant-sensing control
c. A vacancy-sensing control

Figure 5-7: Functional Diagram for Partial-ON Occupant Sensor

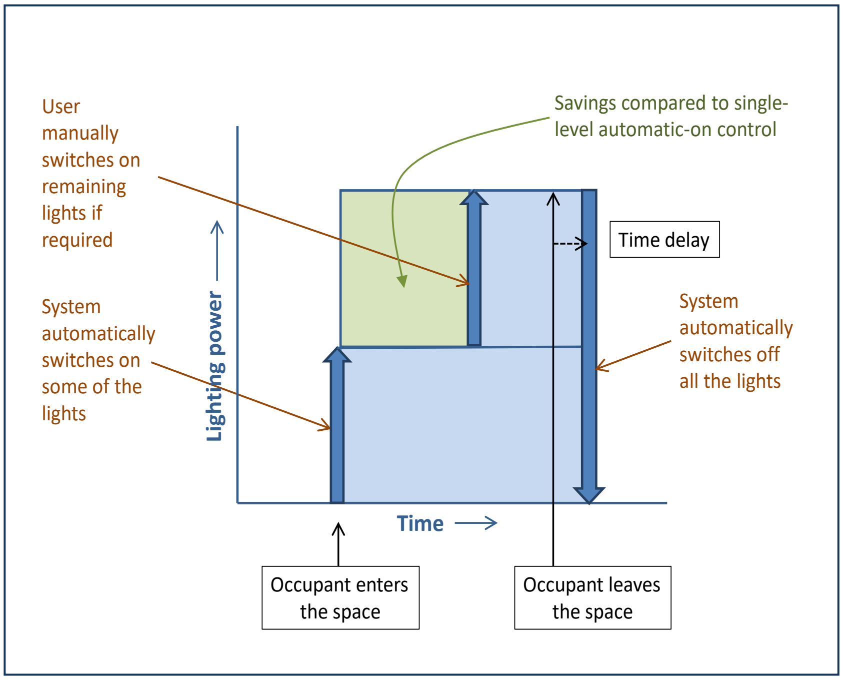


Image Source: California Energy Commission

Offices larger than 250 sq. ft. are required to be equipped with an occupant sensing control that manages the HVAC thermostat setup, setback, and ventilation (§120.1[d]5 and §120.2[e]3). The occupant sensing control for the space must be capable of signaling to the HVAC system the occupancy status of the space independent of the lighting load status.

Using the same occupancy sensors for the lighting and the HVAC system immediately alerts occupants if the occupancy sensors have failed, as the lights would turn off when the space is occupied. An occupancy sensor failure might not be as readily apparent if it controlled the HVAC system only. However, it is not a requirement that the lighting and HVAC systems be controlled by the same occupancy sensor. This method of controlling cooling, ventilation, and lighting satisfies the requirements of §120.1(d)5, §120.2(e)3, and §130.1(c), so no additional shut off controls are required in these spaces (except for lighting associated with the egress path, which may remain energized when the building is unoccupied).

5.4.3.5 Areas Where Full or Partial-Off Occupant Sensing Controls Are Required in Addition to Complying With §130.1(c)1

§130.1(c)6

In addition to the basic shut off requirements in §130.1(c)1, §130.1(c)6 requires full- or partial off occupant sensing controls to turn off or reduce lighting when an area is unoccupied.

In warehouse aisle ways and open areas, certain library book stack aisles, stairwells, and corridors, lighting power must reduce by at least 50 percent when the areas are unoccupied. The decision to reduce or turn lighting off may be made by the designer.

Lighting in these spaces must also comply with §130.1(c)1, which requires lighting to be capable of shutting off when the building is unoccupied. If a partial off occupancy sensor is used to reduce lighting when a space is unoccupied, it can be paired with an automatic time switch to shut lighting off when the building is typically unoccupied.

Figure 5-8 Functional Diagram for Partial Off Occupant Sensor

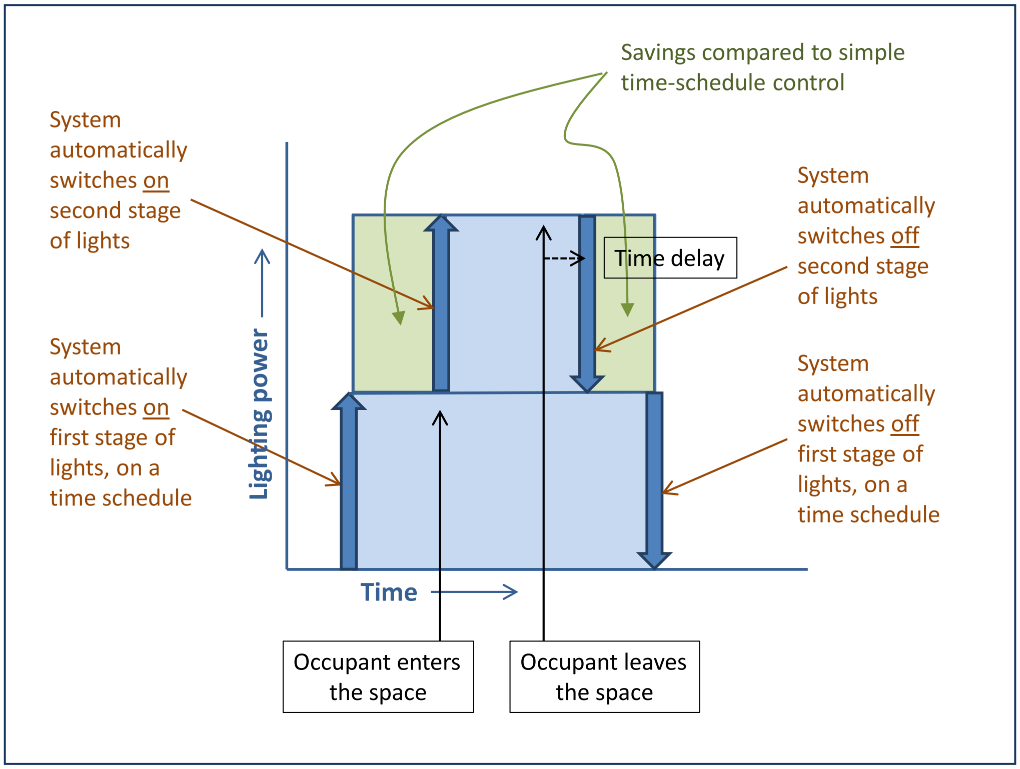


Image Source: California Energy Commission

A. In aisle and open areas in warehouses, lighting shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls must have independent zoning for each aisle, and the aisle zones must not extend beyond the aisle into the open area of the warehouse.

EXCEPTIONS: The following conditions exempt the lighting system from this requirement, but it must meet the additional listed requirements:

1. In aisle ways and open areas in warehouses in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce lighting power by at least 40 percent (instead of the 50 percent required above).
2. When metal halide lighting or high-pressure sodium lighting is installed in warehouses, occupant sensing controls shall reduce lighting power by at least 40 percent (instead of the 50 percent required above). This exception is due to limitations of dimming or bilevel ballast technology for high-intensity discharge (HID) light sources.

B. In the following library book stack aisles, lighting shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied:

1. Library book stack aisles 10 feet or longer that are accessible from only one end
2. Library book stack aisles 20 feet or longer that are accessible from both ends

The occupant sensing controls shall independently control lighting in each aisle way and shall not control lighting beyond the aisle way being controlled by the sensor.

C. In corridors and stairwells, lighting shall be controlled by occupant sensing controls that separately reduce the lighting power in each space by at least 50 percent when the space is unoccupied. The occupant sensing controls shall be capable of turning the lighting fully on automatically only in the separately controlled space and shall be automatically activated from all designed paths of egress.

D. In office spaces greater than 250 sq. ft., general lighting shall be controlled by occupant sensing controls that meet all of the following requirements. These requirements apply exclusively to luminaires providing general lighting. Luminaires not meant to provide general lighting can either be controlled following the same occupant sensing controls requirements as general lighting, or be controlled as specified in §130.1(c)1 using time-switch controls or separate occupant sensing controls.

i. The occupant sensing controls shall be configured so that lighting is controlled separately in control zones not greater than 600 sq. ft. For luminaires with an embedded occupant sensor capable of reducing power independently from other luminaires, each luminaire can be considered its own control zone.

ii. In 20 minutes or less after the control zone is unoccupied, the occupant sensing controls shall uniformly reduce lighting power in the control zone by at least 80 percent of full power. Control functions that switch control zone lights completely off when the zone is vacant meet this requirement.

iii. In 20 minutes or less after the entire office space is unoccupied, the occupant sensing controls shall automatically turn off lighting in all control zones in the space.

iv. In each control zone, lighting shall be allowed to automatically turn on to any level up to full power upon occupancy within the control zone. When occupancy is detected in any control zone in the space, the lighting in other control zones that are unoccupied shall operate at no more than 20 percent of full power.

EXCEPTION to the mandatory occupant sensing controls for offices greater than 250 sq. ft.: Under-shelf or furniture-mounted task lighting that is already controlled by a local switch and either a time clock or an occupancy sensor does not need to be included in the control zones of the occupant sensing controls.

Example 5-5: An Office With Luminaires Serving Different Lighting Purposes

An office of 2,584 square feet has three types of luminaires, as shown in the figure below:

1.Overhead luminaires providing general lighting to the cubicles (the 28 purple rectangles).

2.Linear lights over display cases near the wall highlighting the objects in the cases (bottom left and right).

3.Wall wash lighting along the wall highlighting artwork (bottom center).

Only the overhead luminaires providing general lighting are subject to the occupant sensing control requirements in §130.1(c)6D. Different approaches and options to meet the requirements are discussed in the next example. The linear display lighting and wall wash are grouped together and controlled by a time clock to comply with the shut off requirements in §130.1(c)1.

Figure 5-9 (for Example 5-5) An Office Plan With Occupant Sensing Control Zone Layout

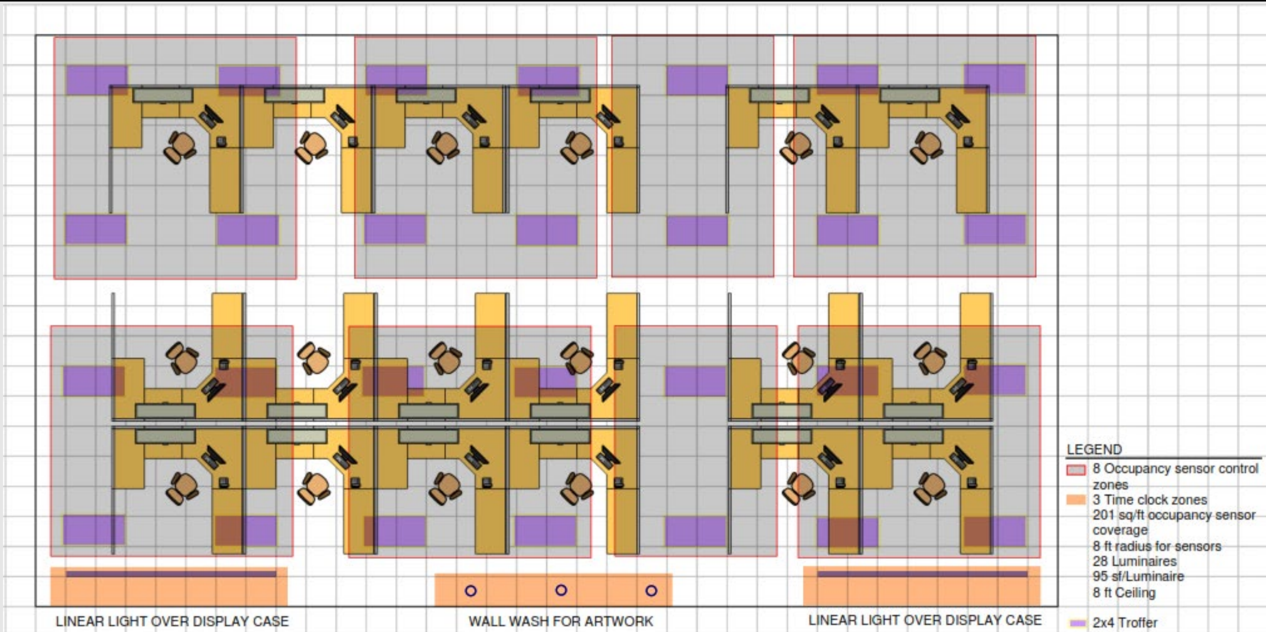


Image Source: Energy Solutions

Example 5-6: Occupant Sensing Control Zones for Office Spaces Greater Than 250 Square Feet

In office spaces greater than 250 sq. ft., the occupant sensing controls must be configured such that general lighting in the space is divided into separate control zones, and the size of each control zone must be 600 sq. ft. or less.

The figure below provides an example of the same 2,584 square foot office as in the previous example that meets this requirement. Display lighting and wall wash are omitted as they do not need to comply with this requirement. In this case, the office is divided into eight occupant sensing control zones, each controlled by an occupant sensor. The occupant sensors in this example have a circular coverage pattern with a radius of 13.5 feet, resulting in a coverage area of 573 square feet, which meets the 600 square feet or less per control zone requirement. Each circle in the image represents the coverage area of the occupant sensor located at the center of the circle. The evenly spaced purple rectangles represent 2’x4’ luminaires that provide general lighting in the office, and the luminaires within each circle are controlled by the occupant sensor at the center of the circle. If a luminaire is in two or more circles, it is controlled by the closest occupant sensor.

The size of each control zone is at the discretion of the practitioner, as long as it is not larger than 600 square feet. The control zones within the office space do not need to be equal in size. If each occupant sensing control zone in an office is 250 square feet or less and the prescriptive compliance path is used, consider taking advantage of the power adjustment factor (PAF) provided in §140.6(a)2I for occupant sensing controls in offices larger than 250 square feet. Refer to Section 5.6.2 for more information on the PAF.

Figure 5-10 (for Example 5-6) An Office Plan With Occupant Sensing Control Zone Layout

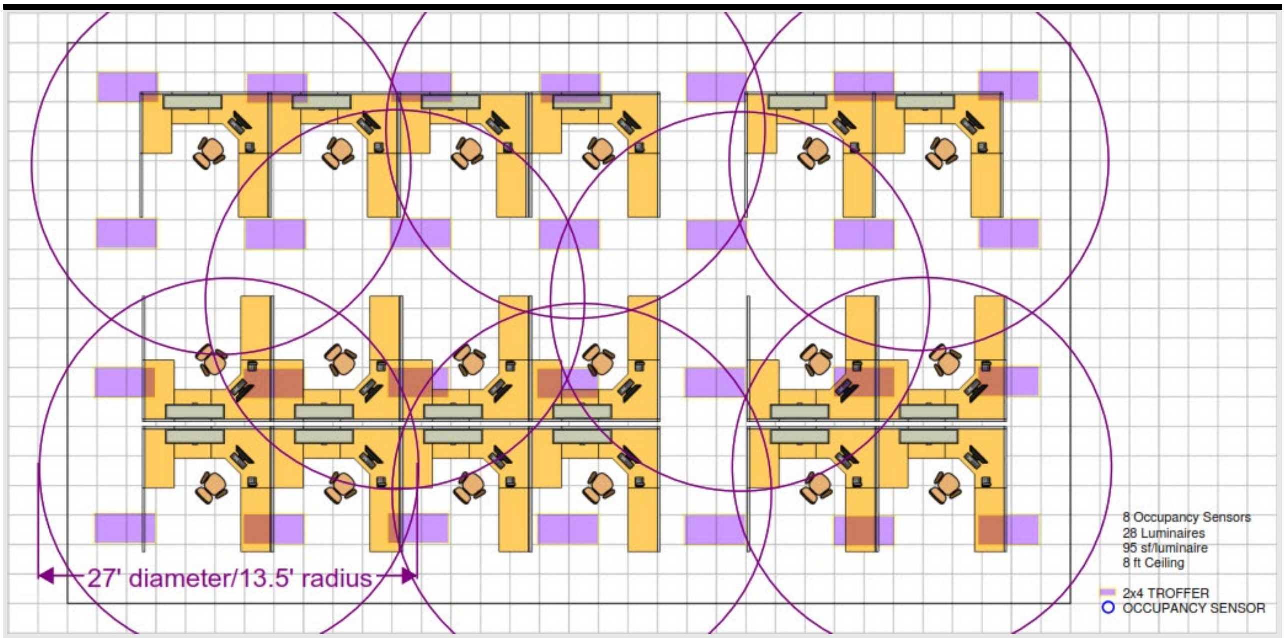


Image Source: Energy Solutions

Example 5-7: Occupant Sensing Control Zone in a Large Office Using Power Adjustment Factor

The figure below shows another occupant sensing control zone design for the same 2,584 sq. ft. office. In this design, 15 occupant sensors are used to meet the requirement, and each sensor has a circular coverage pattern with a radius of 8.5 feet, resulting in a coverage area of 227 sq. ft. Because each sensor controls 227 sq. ft., which is less than 250 sq. ft. but more than 126 sq. ft., a PAF of 0.20 can be used per Table 140.6-A. Refer to §140.6(a)2I and Section 5.6.2 of this compliance manual for detailed requirements on using the PAF for occupant sensing controls in offices larger than 250 square feet.

Note: Using PAFs for occupant sensing controls is dependent on the square footage that each occupant sensor covers and not the number of occupant sensors used. For example, if each of the 15 occupant sensors in the figure below had a coverage area greater than 250 sq. ft., the design would not qualify to use the PAF.

Figure 5-11 (for Example 5-7) An Office Plan With Occupant Sensing Control Zone Layout

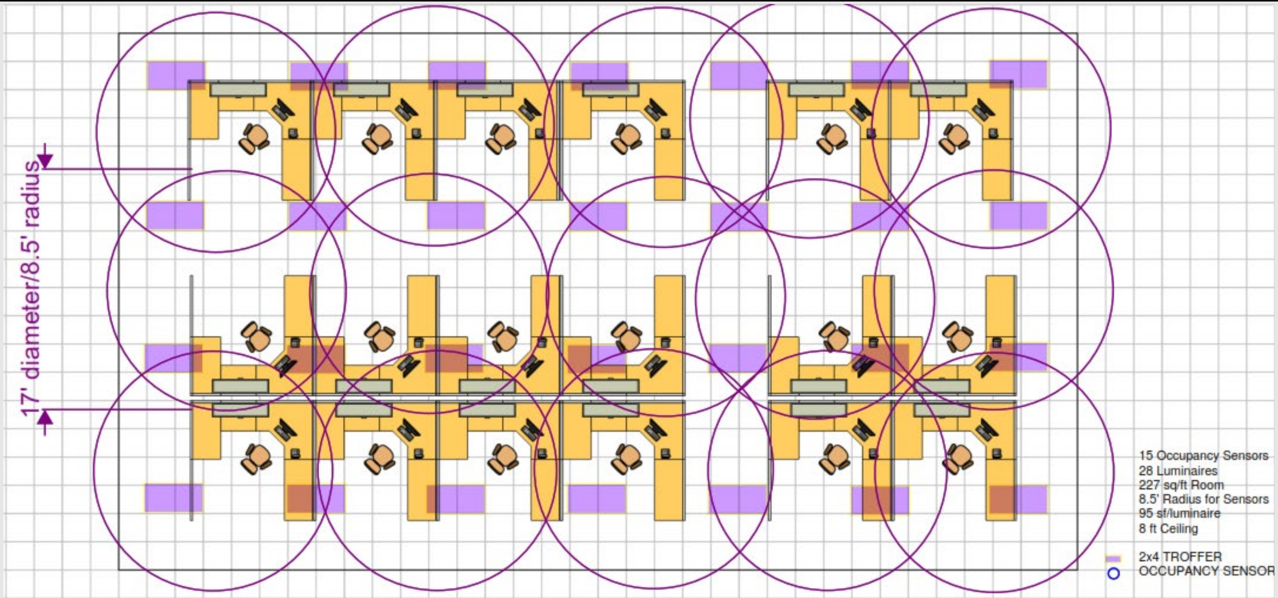


Image Source: Energy Solutions

Example 5-8: Occupant Sensing Control Zones for Luminaires With Integral Occupant Sensors

For luminaires with an integral occupant sensor that are capable of reducing power independently from other luminaires, each luminaire can be considered as its own control zone, and the size of the control zone equals the coverage area of the luminaire-integrated occupant sensor. This configuration is likely to result in occupant sensing control zones 250 sq. ft. or smaller. So, if using the prescriptive compliance path, consider taking advantage of the PAF provided in §140.6(a)2I for occupant sensing controls in offices larger than 250 square feet. Refer to Section 5.6.2 for more about using the PAF.

Note: Each luminaire with an integral occupant sensor can be considered as its own control zone only if they are commissioned to reduce power independently from other luminaires. Several lighting systems allow "grouping" luminaires with an integral occupant sensor. In such a grouping configuration, all luminaires within the group will operate to provide the designed task light level as long as one luminaire-integrated sensor detects occupancy. Similarly, all luminaires will reduce power to 20 percent or less only after no occupant is detected by any of the luminaire-integrated sensors within the group for 20 minutes. In this case, the total area covered by a group of luminaire-integrated occupant sensors is considered as a single occupant sensing control zone and shall be 600 square feet or less.

The figure below provides an example of the same 2,584 sq. ft. office using luminaires with an integral occupant sensor, with each luminaire commissioned to reduce power independently from the other luminaires. In this case, there are 28 luminaires; therefore, there are 28 occupant sensing control zones. The coverage area of each sensor (and therefore the size of each control zone) is 100 sq. ft. This occupant sensing control zone design not only meets the control requirements, but is eligible for a PAF of 0.30 since each occupant sensing control zone is less than 125 sq. ft. (see Table 140.6-A).

Figure 5-12 (for Example 5-8): An Office Plan With Occupant Sensing Control Zone Layout

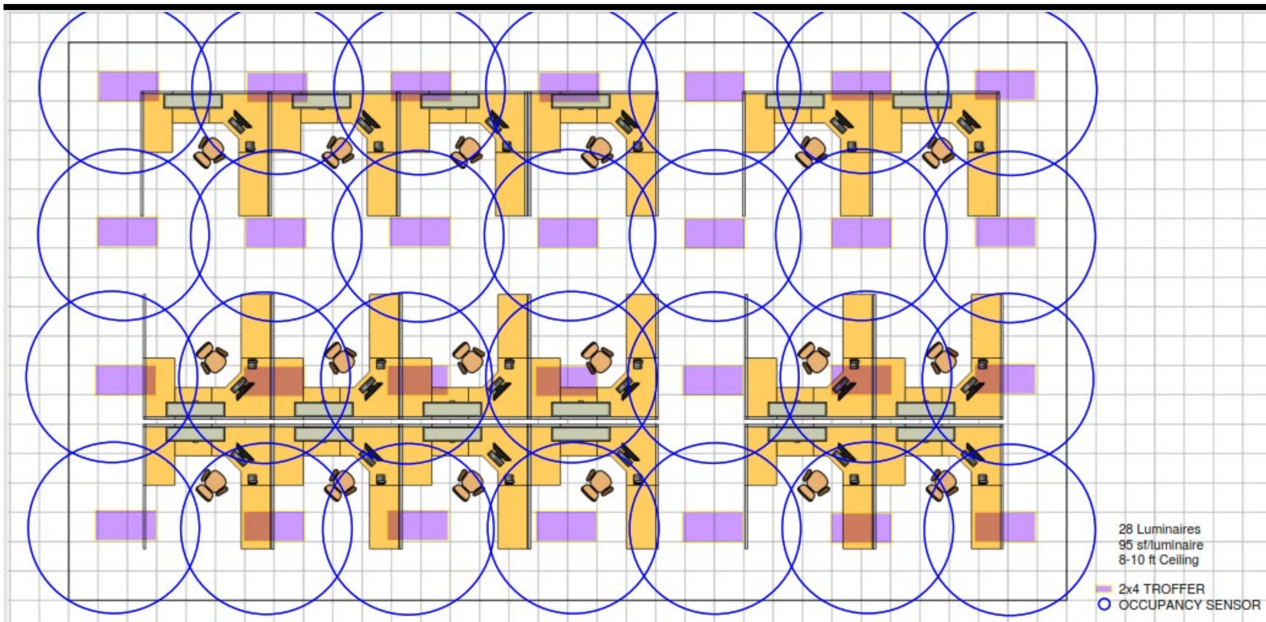


Image Source: Energy Solutions

Example 5-9: Occupant Sensing Controls for an Office Greater Than 250 Square Feet With a Single Control Zone

An office space larger than 250 sq. ft. but smaller than or equal to 600 sq. ft. may have a single control zone for the entire office as long as the field of view of the occupant sensor is able to cover the entire office. The figure below shows a shared office space of 400 square feet as an example. In this case, a single occupant sensor is able to cover the entire office and, therefore, meets the requirement.

Figure 5-13 (for Example 5-9) An Office Plan With Occupant Sensing Control Zone Layout

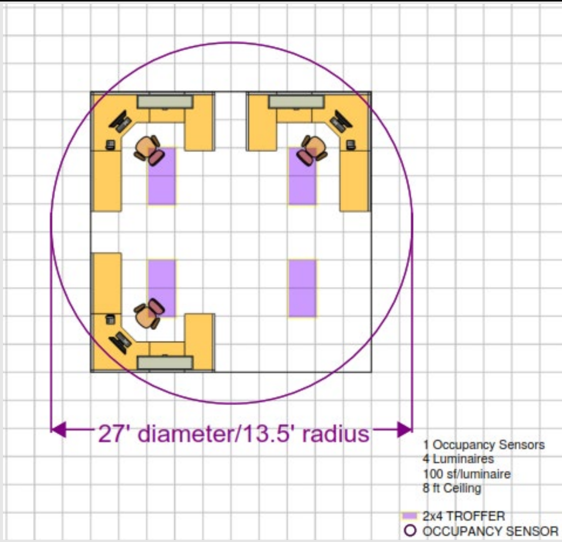


Image Source: Energy Solutions

Notes About Occupant Sensing Ventilation Controls And Occupant Sensing Lighting Controls

Note 1: Occupant sensing ventilation controls are required in spaces meeting, or 7. Occupant sensing ventilation controls for offices greater than 250 sq. ft. are now required because this space type meets both criteria. Because of this, occupant sensing zone controls for the space-conditioning system are also required. Refer to §120.1(d)5 and §120.2(e)3 in the Energy Code as well as Sections 4.3.1.1.1.37 and 4.5.1.1.1.8 of this manual to ensure occupant sensor ventilation controls and occupant sensing zone controls are properly implemented on the mechanical systems. Corridors are another space type covered by §130.1(c)6, where ventilation air is allowed to go to zero during occupied standby mode, and thus are required to meet occupant sensing ventilation control requirements.

Note 2: This occupant sensing controls requirement in §130.1(c)6D does not negate other lighting controls provisions in §130.1. For example, for office spaces greater than 250 sq. ft. where automatic daylighting controls are also required per §130.1(d), lighting in the occupied occupant sensing control zones shall be dimmed in response to the available daylight. Refer to §130.1(f) in the Energy Code and Section 5.4.6 of this manual to ensure the proper interactions among the required lighting controls.

5.4.3.6 Areas Where Partial-Off Occupant Sensing Controls Are Required Instead of Complying With §130.1(c)1

§130.1(c)7

In stairwells and common area corridors to guest rooms of hotel/motels, in parking garages and parking areas, and in loading and unloading areas, lighting is required to have partial off occupant sensing controls instead of meeting the shut off requirements of §130.1(c)1.

Lighting in these spaces may operate full time at the minimum setback level and is not required to be shut off after hours. The decision to turn the lights off fully may be made by the designer.

A. Lighting in stairwells and common area corridors that provide access to guestrooms of hotel/motels shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully on only in the separately controlled space and shall be automatically activated from all designed paths of egress.

   This permits the lights to remain on at a setback level continuously. The zoning of the controls requires careful consideration of paths of egress to ensure that sensor coverage in the zone is adequate.

   EXCEPTION: In common area corridors and stairwells in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce power by at least 40 percent (instead of the normally required 50 percent).

B. In parking garages, parking areas, and loading and unloading areas, general lighting shall meet the following requirements:

   1. Be controlled by occupant sensing controls having at least one control step between 20 percent and 50 percent of design lighting power.
   2. No more than 500 watts of rated lighting power shall be controlled together as a single zone.
   3. A reasonably uniform level of illuminance shall be achieved in accordance with the applicable requirements in Table 5-1 (Table 130.1-A of the Energy Code).
   4. Occupant sensing controls shall be capable of automatically turning the lighting fully on only in each separately controlled space.
   5. The occupant sensing controls shall be automatically activated from all designed paths of egress.

For these spaces, lighting power must be reduced by at least 50 percent of the design lighting power, and the lighting must be reduced while maintaining similar levels of uniformity to the full power conditions. The zoning of the controls requires careful consideration of paths of egress to ensure that the sensor coverage in the zone is adequate. The wattage limits per zone will typically not permit entire floors of a garage to be on a single zone.

EXCEPTION: Metal halide luminaires meeting both of the following criteria shall be controlled by occupant sensing controls having at least one control step between 20 percent and 60 percent of design lighting power:

- A "lamp plus ballast" means system efficacy greater than 75 lumens per watt. (The lamp plus ballast mean system efficacy is the rated mean lamp lumens at 40 percent of lamp life[1] divided by the ballast rated input watts.)
- When metal halide is used for general lighting in parking garages, parking areas, and loading and unloading areas.

The requirement for metal halide luminaires to have a control step between 20 percent and 60 percent is a limitation of the dimming or bilevel ballast technology in HID light sources.

Interior areas of parking garages are classified as indoor lighting for compliance with §130.1(c)7B.

The parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provisions in §130.2. Controls requirements in §130.1(c)7B do not apply to open rooftop parking.

5.4.4 Automatic Daylighting Controls

§130.1(d)

Daylighting can be used as an effective strategy to reduce electric lighting energy use by reducing electric lighting power in response to available daylight. Section 130.1(d) addresses mandatory requirements for automatic daylighting controls.

Automatic daylighting controls are required in daylit zones to automatically reduce general lighting when sufficient daylight is available.

5.4.4.1 Daylit Zones and Controlling Lighting in Daylit Zones

Terms:

Daylit Zone is the floor area under skylights or next to windows. Types of Daylit Zones include Primary Sidelit Daylit Zone, Secondary Sidelit Daylit Zone, and Skylit Daylit Zone.

Primary Sidelit Daylit Zone is the area in plan view directly adjacent to each vertical glazing, one window head height deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the

1 Illuminating Engineering Society. Section 13.3 "Life and Lumen Maintenance" in *The Lighting Handbook: 10th Edition Reference and Application*. 2011. New York.

window, minus any area on a plan beyond a permanent obstruction that is 6 feet or taller as measured from the floor.

Secondary Sidelit Daylit Zone is the area in plan view directly adjacent to each vertical glazing, two window head heights deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window, minus any area on a plan beyond a permanent obstruction that is 6 feet or taller as measured from the floor.

Skylit Daylit Zone (see below).

Window Head Height — The vertical distance from the finished floor level to the top of a window or vertical fenestration.

There are three types of daylit zones: primary sidelit daylit zone, secondary sidelit daylit zone, and skylit daylit zone.

A. **Skylit Daylit Zone** is the rough area in plan view under each skylight, *plus* 0.7 times the average ceiling height in each direction from the edge of the rough opening of the skylight, *minus* any area on a plan beyond a permanent obstruction that is taller than one-half the distance from the floor to the bottom of the skylight.

   Note: Modular furniture walls should not be considered a permanent obstruction.

The bottom of the skylight is measured from the bottom of the skylight well (for skylights having wells), or the bottom of the skylight if no skylight well exists.

For determining the skylit daylit zone, the geometric shape of the skylit daylit zone shall be identical to the plan view geometric shape of the rough opening of the skylight; for example, the skylit daylit zone for a rectangular skylight must be rectangular. For a circular skylight, the skylit daylit zone must be circular.

Figure 5-14: Example of Skylit Daylit Zone Layout in Overhead View

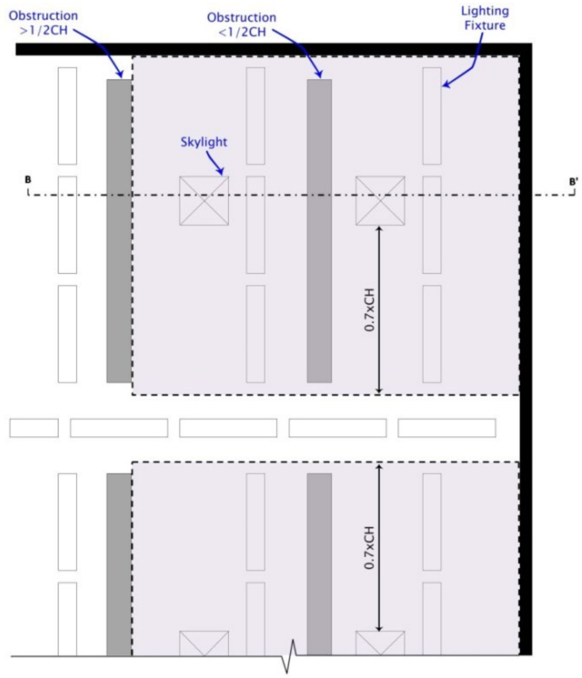


Image Source: California Energy Commission

Figure 5-15: Example of Skylit Daylit Zone Layout in Side View

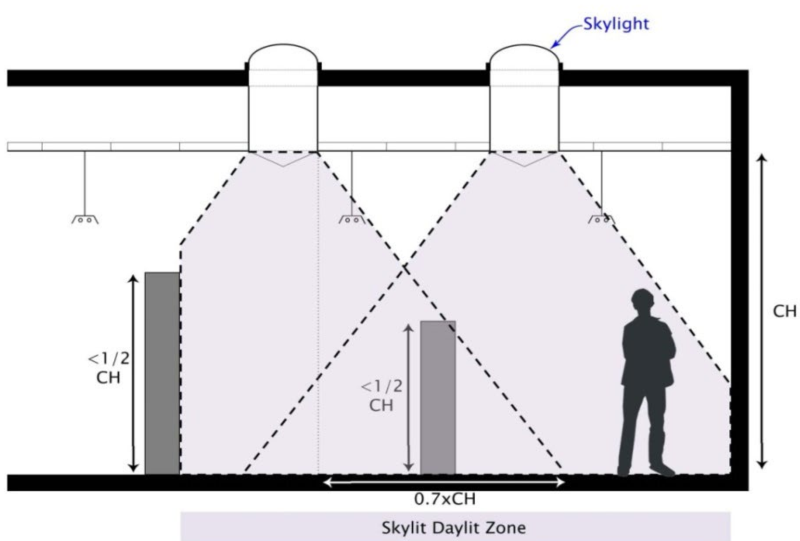


Image Source: California Energy Commission

B. PRIMARY SIDELIT DAYLIT ZONE is the area in plan view directly adjacent to each vertical glazing, one window head height deep into the area, and window width *plus* 0.5 times window head height wide on each side of the rough opening of the window, *minus* any area on a plan beyond a permanent obstruction that is 6 feet or taller as measured from the floor.

Note: Modular furniture walls should not be considered a permanent obstruction.

Figure 5-16: Example of Primary Sidelit Daylit Zone Layout in Overhead View

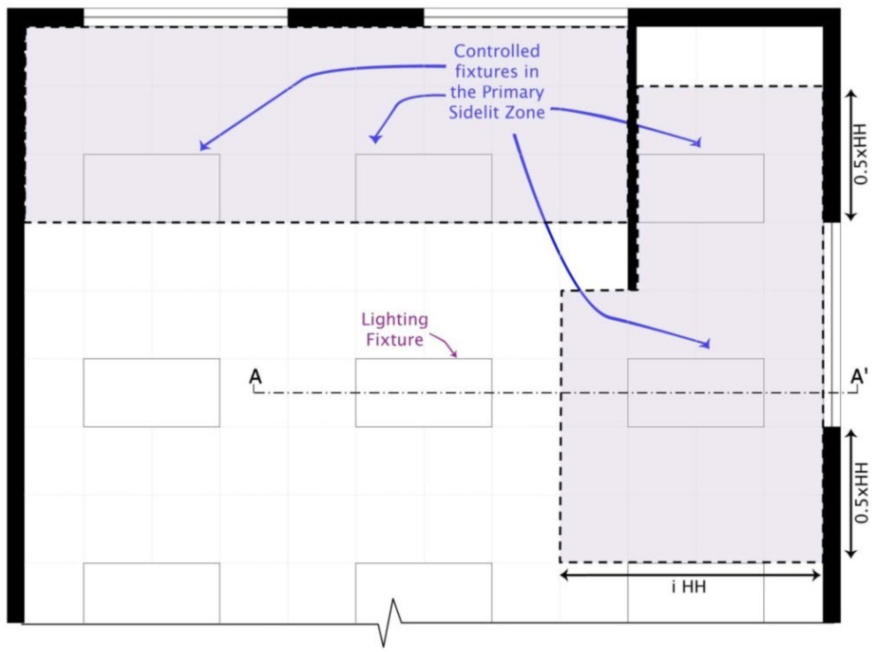


Image Source: California Energy Commission

Figure 5-17: Example of Primary Sidelit Daylit Zone Layout in Side View

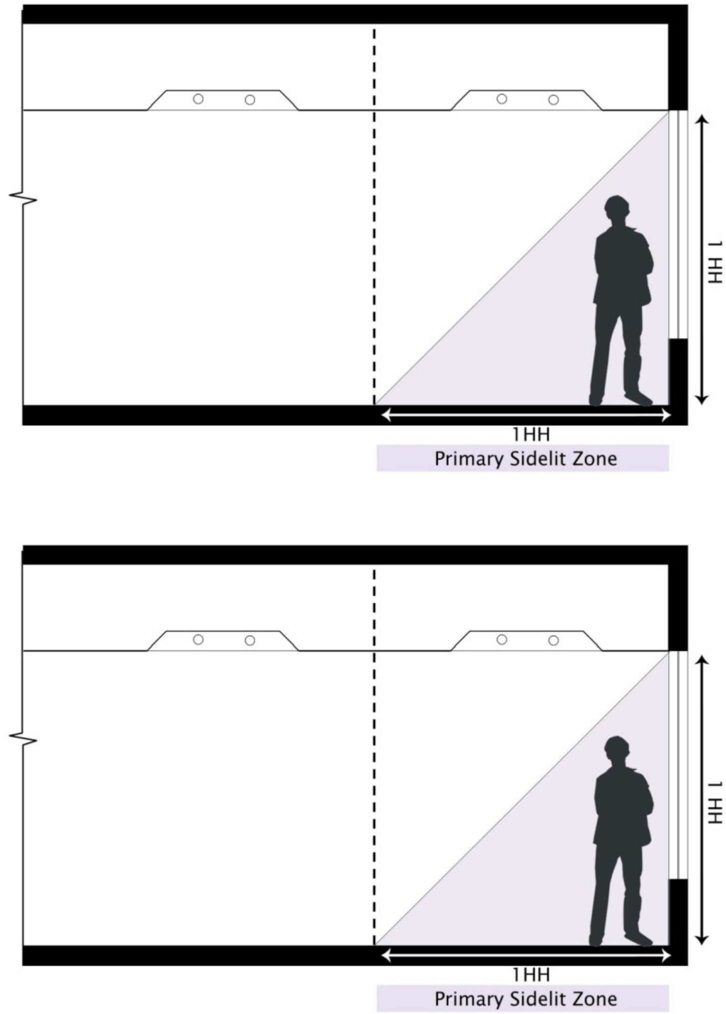


Image Source: California Energy Commission

C. **SECONDARY SIDELIT DAYLIT ZONE** is the area in plan view directly adjacent to each vertical glazing, two window head heights deep into the area, and window width *plus* 0.5 times window head height wide on each side of the rough opening of the window, *minus* any area on a plan beyond a permanent obstruction that is 6 feet or taller as measured from the floor.

   Note: Modular furniture walls should not be considered a permanent obstruction.

Figure 5-18: Example of Secondary Sidelit Daylit Zone in Side View

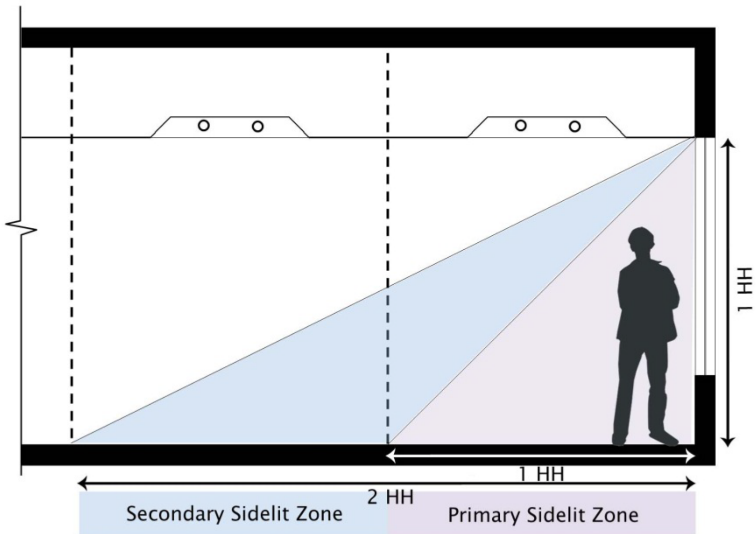


Image Source: California Energy Commission

Figure 5-19: Example of Secondary Sidelit Daylit Zone in Overhead View

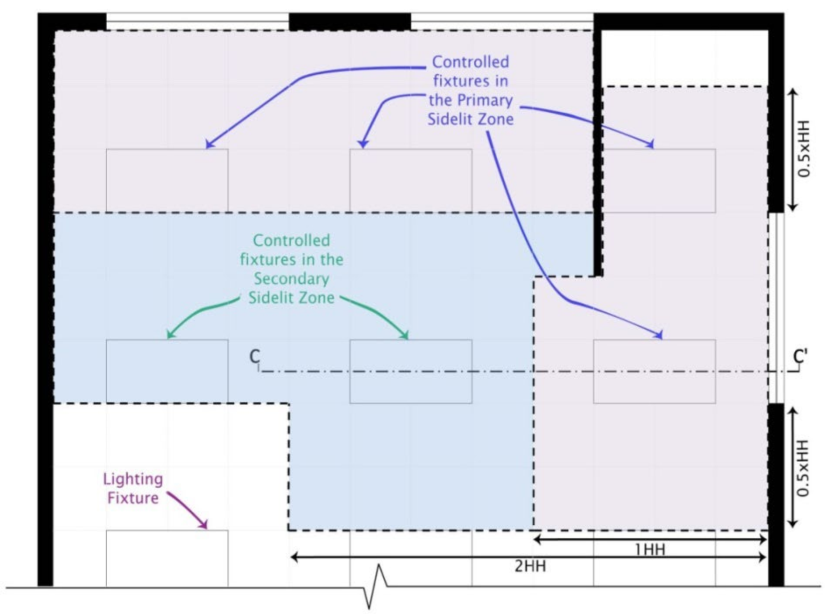


Image Source: California Energy Commission

5.4.4.2 Automatic Daylighting Controls in and for Daylit Zones

Automatic daylighting controls are required for general lighting in skylit daylit zones, primary sidelit daylit zones, and secondary sidelit daylit zones.

The requirements are as follows:

A. Luminaires providing general lighting that are at least 50 percent in the skylit daylit zone, primary sidelit daylit zone, or secondary sidelit daylit zone shall be controlled independently by automatic daylighting controls that meet the applicable requirements:

1. All skylit daylit zones, primary sidelit daylit zones, and secondary sidelit daylit zones must be shown on the building plans.
2. The automatic daylighting controls shall provide separate control for general lighting in each type of daylit zone. General lighting luminaires in the skylit daylit zone must be controlled separately from those in the primary sidelit daylit zone and secondary sidelit daylit zone.

   In spaces where skylights are near exterior walls with windows, the skylit daylit zone may overlap with either the primary or secondary sidelit daylit zone. The skylit daylit zone takes precedence, and the general lighting luminaires in the overlapping area must be controlled as part of the skylit daylit zone.
3. Where the primary sidelit daylit zone and the secondary sidelit daylit zone overlap, such as in corner spaces, the primary sidelit daylit zone takes precedence and the general lighting luminaires in the overlapping area must be controlled as part of the primary sidelit daylit zone.
4. General lighting luminaires that are long such as linear pendants, strip lights, tape lights, and cover lights shall be segmented into control sections so that lighting is controlled separately in skylit daylit zones, primary sidelit daylit zones, secondary sidelit daylit zones, and nondaylit zones. Each segment must be 4 feet or shorter and be separately controlled according to the type of daylit zone in which the segment is primarily located.

5.4.4.3 Automatic Daylighting Control Installations and Operations

For luminaires in skylit daylit zones, primary sidelit daylit zones, and secondary sidelit daylit zones, automatic daylighting controls must be installed and configured according to the following requirements:

1. Automatic daylighting controls must provide multiple lighting levels with at least the number of control steps specified in Table 5-1 (Table 130.1-A of the Energy Code).

   When the requirements of §130.1(d) are triggered by the addition of skylights to an existing building and the lighting system is not recircuited, the daylighting control is not required to meet the multilevel requirements in §130.1(d). The daylighting control may provide on/off control in accordance with §141.0(b)2 for alterations.

2. For each space, the combined illuminance from the controlled lighting and daylight shall not be less than the illuminance from controlled lighting when no daylight is available.

   In the darkest portion of the daylit zone, the control should not overdim the lights.

3. When the daylight illuminance is greater than 150 percent of the illuminance provided by the controlled lighting when no daylight is available, the controlled lighting power in that daylight zone shall be reduced by a minimum of 90 percent.

   The best control would fully dim the system when daylight levels in the darkest portion of the daylit zone are at 100 percent of the illuminance from controlled lighting when no daylight is available. The 150 percent/90 percent requirement allows some tolerance for error while obtaining most of the energy savings.

4. Photosensors shall be located so they are not readily accessible to unauthorized personnel. The location where calibration adjustments are made to automatic daylighting controls shall be readily accessible to authorized personnel and may be inside a locked case or under a cover that requires a tool for access. Access to controls can be limited by placing locks or screws on enclosures or under a cover plate so a tool or key is needed to gain access. Though not required, commissioning and retrocommissioning of the control are simplified if the calibration adjustments are readily accessible to authorized personnel so that a lift or a ladder is not required to access the location where calibration adjustment are made.

   Some controls have wireless remotes for adjusting settings. This allows one person with a light meter and the wireless calibration tool to be located at the edge of the daylit zone and make the calibration adjustments without having to run back and forth between taking the measurement and making the adjustment.

   EXCEPTIONS: Automatic daylighting controls are not required for any of the following conditions:

   - Areas under skylights where it is documented that existing adjacent structures or natural objects block direct sunlight for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.
   - Areas adjacent to vertical glazing below an overhang, where the overhang covers the entire width of the vertical glazing, no vertical glazing is above the overhang, and the ratio of the overhang projection to the overhang rise is greater than 1.5 for south, east, and west orientations or greater than 1 for north orientations.

- Rooms in which the combined total installed wattage of general lighting power in skylit daylit zones and primary sidelit daylit zone is less than 120 watts are not required to have daylighting controls for those zones.
- Rooms where the total installed wattage of general lighting power in secondary sidelit daylit zones is less than 120 watts are not required to have daylighting controls for those zones.
- Rooms that have a total glazing area of less than 24 square feet.
- Luminaires in sidelit daylit zones in retail merchandise sales and wholesale showroom areas.

Example 5-10: Complying With the 150 Percent of the Design Illuminance Daylighting Requirement

When the illuminance received from daylight is greater than 150 percent of the design illuminance (or nighttime electric lighting illuminance), the general lighting power in the daylit zone must reduce by a minimum of 90 percent.

For example, a space has 500 watts of general lighting power in the daylit zones. The design illuminance for the space is 50 foot-candles (fc). When the available daylight in the space reaches 75 fc (that is, 150 percent of 50 fc), then the power consumed by the general lighting in the daylit zones should be 50 watts or lower.

Without checking all points in the daylit zone served by controlled lighting, verifying that the requirements are met at a worst-case location far away from windows or skylights is sufficient. This location is called the "Reference Location."

Example 5-11: Daylighting Controls and Opaque Curtain Walls

Question

Are automatic daylighting controls required for daylit zones adjacent to opaque glazing in curtain walls per §130.1(d) and §140.6(a)?

Answer

No. The automatic daylighting control requirements do not apply to daylit zones adjacent to opaque curtain walls. The Energy Code defines sidelit daylit zones as the areas in plan view directly adjacent to each vertical glazing. Glazing is a fenestration product that is defined as being transparent or translucent. Note: Automatic daylighting control requirements will apply to daylit zones adjacent to transparent or translucent curtain walls.

Example 5-12: Sidelit Daylit Zone for a Recessed Window

Question

Are sidelit daylit zones determined differently for an area adjacent to a window that is recessed in a bay?

Answer

No. The sidelit daylit zones will be determined the same way as for a window that is not recessed. The primary sidelit daylit zone extends out one window head height deep into the space and one-half a window head height to each side of the rough opening of the window. The only difference is that the sidelit daylit zone of a recessed window will be reduced by the incursion of the bay and exterior walls into the sidelit daylit zone, as shown in the following figure.

Figure 5-20: (Example 5-12) Sidelit Daylit Zone Layout for a Bay Window

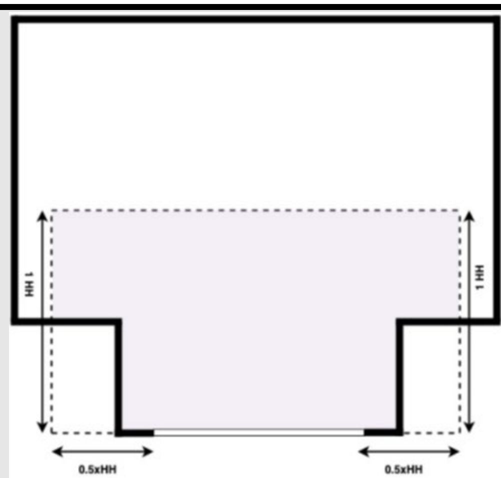


Image Source: California Energy Commission

5.4.4.4 Automatic Daylighting Controls in and for Parking Garages

In a parking garage area having a combined total of 36 square feet or more of glazing or opening, luminaires providing general lighting that are in the combined primary and secondary sidelit daylit zones shall be controlled independently from other lighting in the parking garage by automatic daylighting controls.

Parking areas on the roof of a parking structure are outdoor hardscape and automatic daylighting control requirements do not apply to these spaces.

The primary differences between the automatic daylight control requirements in parking garages and the rest of interior lighting spaces are the following:

- The primary and secondary sidelit daylit zones are controlled together in parking garages, whereas they must be separately controlled in other spaces. However, it is permissible that in either space type, a single sensor can be used if the control system can make the appropriate light level adjustments in each zone.

- In parking garages, when the daylight illuminance is greater than 150 percent of the illuminance provided by the controlled lighting when no daylight is available, the controlled lighting power in the combined primary and secondary sidelit daylight zone shall be reduced by 100 percent. (In other interior spaces, the lighting power must be reduced by 90 percent.) Egress lighting for the parking garage may be controlled, but the controls must employ a fail-safe mechanism that ensures that the egress lighting is functioning and stays on if the photocell fails.

Exceptions: Automatic daylighting controls are not required in the following parking garage areas:

- Parking garage areas where the total installed wattage of general lighting in the primary and secondary sidelit daylit zones is less than 60 watts
- Parking garage areas with a total glazing or opening area less than 36 square feet
- Luminaires in the daylight adaptation zone

5.4.5 Demand-Responsive Lighting Controls

§130.1(e); §110.12

Buildings with nonresidential lighting systems having a total installed lighting power of 4,000 watts or greater that are subject to the multilevel requirements in §130.1(b) must meet demand-responsive lighting control requirements.

The demand-responsive control must be capable of reducing the total lighting power by 15 percent or greater. The lighting power reduction must meet the uniformity requirements of Table 130.1-A

EXCEPTION: Spaces where a health or life safety statute, ordinance, or regulation does not permit the general lighting to be reduced are exempted from the requirement and do not count toward the 4,000 watt threshold.

See Appendix D for guidance on compliance with the demand-responsive control requirements.

Example 5-13: Demand-Responsive Lighting Controls 15 Percent Reduction in Lighting Power

Question

What lighting counts toward the 4,000 watt demand-responsive lighting threshold? If this threshold is exceeded, what lighting must have demand-responsive lighting controls? What lighting counts toward the 15 percent minimum reduction?

Answer

Only general lighting that is subject to multilevel requirements in §130.1(b) counts toward the 4,000 watt threshold. When this threshold is exceeded, demand-responsive controls are required for general lighting.

The demand-responsive controls must be capable of reducing the total lighting power by a minimum of 15 percent. This includes general lighting and any additional lighting such as task, display, or other lighting. For example, consider an office that has 5,000 total installed watts of general lighting subject to §130.1(b) and 2,000 watts of additional lighting power. While only the 5,000 watts of general lighting are required to have demand response controls per §110.12(c), the 15 percent reduction is based on the 7,000 total installed watts in the office.

5.4.6 Lighting Control Interactions — Considerations for Spaces With Multiple Lighting Control Types

§130.1(f)

Indoor lighting systems subject to §130.1 require multiple types of lighting controls. Section 130.1(f) includes the requirements for control interactions between manual area controls, multilevel controls, shut off controls, daylighting controls, and demand-responsive controls.

Example 5-14: Interaction Between Manual Dimming and Automatic Daylighting Controls

Question

For a space with manual dimming control and automatic daylighting controls, can the manual dimming control override the automatic daylighting control?

Answer

Yes. Section 130.1(f) includes requirements for control interactions between lighting control types.

The automatic daylighting control must allow the multilevel lighting control to adjust the level of lighting. This means an occupant can use the dimming control to increase or decrease the lighting level as necessary and override the automatic daylighting control.

Additionally, the multilevel lighting control must allow the automatic daylighting control to adjust the electric lighting level in response to changes in the amount of daylight in the daylit zone.

5.4.6.1 Practical Considerations

For a space with both daylighting controls and dimming controls, the daylighting controls are likely to be the primary control most of the time. When the building user/occupant wants to use the dimming control to adjust the light level, they should be able to do so. The user should be able to manually override the level of light provided by the lighting system with manual dimming and a scene feature (switching the lighting in the zone to the predefined level) according to the needs of the activity.

One method to achieve this would be for the occupant use the dimmer control to lower or raise the upper bound on the amount of light provided by the electric lighting. The dimming control would temporarily set a total lighting level that the daylighting control could then achieve by balancing the amount of electric lighting with the daylighting available in the space. This method allows the occupant to receive the benefits of both controls, rather than one control locking out the use of the other. When the activity is over, the lighting system should be restored to automatic control operation.

There is another method for spaces with all three control types — dimming, shut off, and daylighting. If the occupant sensing control is the shut off control, the lighting should restore to automatic control mode. (The occupant sensing control is triggered within 20 minutes after the area has been vacated.) If there are no occupant sensing controls and if an override is initiated, the automatic control should be overridden for no more than 20 minutes. After that, the automatic control resumes, and the light level should be set by the daylighting controls.

5.4.7 Lighting Control Functionality

§110.9(b)

All installed lighting control devices and systems must meet the functionality requirements in §110.9(b). In addition, all components of a lighting control system installed together must meet the applicable requirements in §130.0 through §130.5, §140.6 through §140.8, §141.0, and §150.0(k).

To ensure compliance with the requirements of §110.9(b), designers and installers should review features of their specified lighting control products as part of code compliance.

A. Time-Switch Lighting Controls

Time-switch lighting control products shall provide the functionality listed in §110.9(b)1.

B. Daylighting Controls

Daylighting control products shall provide the functionality listed in §110.9(b)2.

C. Dimmers

Dimmer products shall provide the functionality listed in §110.9(b)3.

D. Occupant Sensing Controls

Occupant sensing control products (including occupant sensors, partial-on occupant sensors, partial-off occupant sensors, motion sensors, and vacancy sensor controls) shall provide the functionality listed in §110.9(b)4 and §110.9(b)6.

Occupant sensing controls must be capable of automatically reducing the lighting or turning the lighting off within 20 minutes after the area has been vacated.

5.4.8 Track Lighting Integral Current Limiters and Track Lighting Supplementary Overcurrent Protection Panels

§110.9(c) and (d)

A **track lighting current limiter limits** the power that can go through a section of track lighting. Without the current limiter, the "installed" wattage of a long section of track could be excessive and use up the allotted lighting power for a space. With track lighting and a current limiter, the track heads can be placed anywhere along the run of the track as long as the total wattage of all heads on the track stays below the rated wattage of the current limiter. If the wattage exceeds the rated wattage of the current limiter, the limiter turns off current to the controlled lighting.

Track lighting integral current limiters must meet the requirements in §110.9(c):

1. Have the volt-ampere (VA) rating clearly marked as follows:
    - So that it is visible for the local enforcement agency's field inspection without opening cover plates, fixtures, or panels.
    - Permanently marked on the circuit breaker.
    - On a factory-printed label permanently affixed to a nonremovable baseplate inside the wiring compartment.
2. Have a conspicuous factory installed label permanently affixed to the inside of the wiring compartment warning against removing, tampering with, rewiring, or bypassing the device.
3. Have a factory installed, prominently located label containing the text in §110.9(c)3.

A **track lighting supplementary overcurrent protection panel** is a subpanel that contains current limiters for use with multiple track lighting circuits only. A track lighting supplementary overcurrent protection panel shall be used only for line-voltage track lighting and shall meet the requirements specified in §110.9(d) and paraphrased below:

1. Be listed as defined in §100.1
2. Have a factory-installed, prominently located label containing the text in §110.9(d)2

5.5 Prescriptive Requirements for Daylighting Devices and for Large Enclosed Spaces

The following are the prescriptive requirements for daylighting devices (clerestories, horizontal slats, and light shelves) that qualify for PAFs and for daylighting in large, enclosed spaces.

5.5.1 Daylighting Device (Clerestories, Horizontal Slat, and Light Shelves) Power Adjustment Factors

§140.6(a)2L

Certain design features and technologies can increase the daylighting potential of spaces. Some of these design features and technologies may be used in conjunction with automatic daylighting controls to receive PAFs from Table 140.6-A or as a performance compliance option in the performance method.

A careful analysis should be performed to avoid glare when including daylighting devices in a design. For example, specularly reflective (e.g., polished or mirror-finished) slats may redirect sunlight and cause uncomfortable glare. Since that is not the only consideration to make when considering daylighting design features, a careful daylighting analysis should be performed on a space-by-space, project-by-project basis.

The daylight dimming plus off PAF and institutional tuning in daylit areas may be added to any of the daylighting design PAFs to create a combined total PAF.

In addition, the horizontal slat PAF can be added to the clerestory fenestration PAF if the requirements for both are met.

In the performance method, a variety of control strategies is available in the compliance software to take advantage of further savings.

At permit application, use form NRCC-LTI-E to document daylighting device PAFs.

5.5.2 Daylighting Requirements for Large, Enclosed Spaces

§140.3(c)

Section 140.3 has prescriptive requirements for building envelopes, including daylighting for large, enclosed spaces directly under roofs. Lighting installed in these spaces is required to comply with all lighting control requirements, including the automatic daylighting control requirements. Mandatory daylighting control requirements are covered in Section 5.4.4 of this chapter.

For projects that comply with the prescriptive daylighting requirements by installing daylight openings in large, enclosed spaces directly under roofs, the daylit areas may require automatic daylighting controls. However, for projects using the performance approach, it is possible to displace the daylighting openings and daylighting controls with other building efficiency options

5.5.2.1 Large, Enclosed Spaces Requiring Daylighting — Qualifying Criteria

The prescriptive daylighting requirements for large, enclosed spaces apply to both conditioned and unconditioned nonresidential spaces that meet the following qualifying criteria:

1. Directly under a roof.
2. Located in Climate Zones 2 through 15.
3. Have a floor area greater than 5,000 sq ft.
4. Have a ceiling height greater than 15 ft.

   EXCEPTIONS:

   1. Auditoriums, churches, movie theaters, museums, and refrigerated warehouses.
   2. Enclosed spaces having a designed general lighting system with a lighting power density less than 0.5 W/ft^2.
   3. In buildings with unfinished interiors, future enclosed spaces in which there are plans to have one of the following:
      a. A floor area of less than or equal to 5,000 sq. ft.
      b. Ceiling heights less than or equal to 15 feet. This exception shall not be used for S-1 or S-2 (storage) or F-1 or F-2 (factory) occupancies.
   4. Enclosed spaces where it is documented that permanent architectural features of the building, existing structures, or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1,500 hours per year between 8 a.m. and 4 p.m.

5.5.2.2 Prescriptive Daylighting Requirements

In Climate Zones 2 through 15, enclosed spaces larger than 5,000 sq. ft. shall have at least 75 percent of the floor area within the primary sidelit daylit zone or skylit daylit zone.

Enclosed spaces that are required to comply must meet the following prescriptive daylighting requirements:

1. A combined total of at least 75 percent of the floor area, as shown on the plans, shall be within the skylit daylit zone or primary sidelit daylit zone. The calculation of the daylit zone area to show compliance with this minimum daylighting requirement does not need to account for the presence of partitions, stacks, or racks, other than those that are ceiling-height partitions. The envelope may be designed before there is any knowledge of the location of such obstructions, as is often the case for core and shell buildings. Thus,

the architectural daylit zone requirement of 75 percent of the enclosed space indicates the possibility of the architectural space being mostly daylit.

The daylit zone and controls specification in §130.1(d) describe which luminaires are controlled. The obstructing effects of tall racks, shelves, and partitions must be taken into consideration when determining the specifications. The electrical design will likely occur later than the architectural design; thus, planning for these obstructions can be built into the lighting circuiting design. With addressable luminaires, the opportunity is available to the contractor to incorporate the latest as built modifications into the daylight control grouping of luminaires according to unobstructed access to daylight.

2. The total skylight area is at least 3 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of the rough opening of the skylights; or the product of the total skylight area and the average skylight visible transmittance is no less than 1.5 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of the rough opening of skylights.

   The above two requirements are represented by the following equations.

$$\frac{Skylight\ Area}{Daylit\ Zone\ under\ skylights} \geq 3\ percent\ of\ total\ floor\ area \quad (Equation\ 5-1)$$

$$Skylight\ Area \times VT \geq 1.5\ percent\ \times Daylit\ Zone\ under\ skylights \quad (Equation\ 5-2)$$

Definitions of the above equation terms:

Skylight Area = Total skylight area on the roof

Daylit Zone under skylights = Total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of the rough opening of skylights

VT = Visible Transmittance

3. General lighting in daylit zones shall be controlled in accordance with §130.1(d).
4. Skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003 or other test method approved by the CEC.

   Skylights must also meet the maximum glazing area, thermal transmittance (U-factor), solar heat gain coefficient (SHGC), and visible transmittance (VT) requirements of §140.3(a). Plastic skylights are required to have a VT of 0.64 and glass skylights are required to have a VT of 0.49. Currently, plastics are not accompanied by low-emissivity films, which transmit light but block most of the rest of the solar spectrum. As a result, there is no maximum SHGC for plastic skylights. Glass skylights are required to have a maximum SHGC of 0.25. With a maximum SHGC of 0.25 and a minimum VT of 0.49, glass skylights must use low-emissivity films or coatings that have a high light-to-solar gain ratio.

5. All skylit daylit zones and primary sidelit daylit zones shall be shown on building plans.

The total skylight area on the roof a building is prescriptively limited to a maximum of 5 percent of the gross roof area (§140.3[a]6A).

Example 5-15: Using Skylights to Meet the Daylighting Requirement for Large Enclosed Spaces

In buildings with large, enclosed spaces that must meet the minimum daylighting requirement, the core zone of many of these spaces will be daylit with skylights. Skylighting 75 percent of the floor area is achieved by evenly spacing skylights across the roof of the zone. A space can be fully skylit by having skylights spaced so that the edges of the skylights are not farther apart than 1.4 times the ceiling height. Therefore, in a space having a ceiling height of 20 feet, the space will be fully skylit if the skylights are spaced so there is no more than 28 feet of opaque ceiling between the skylights.

Example 5-16: Large, Enclosed Spaces in a Warehouse Building

Question

For a 40,000 sq. ft. warehouse with a 30-foot ceiling (roof deck) height, what is the maximum skylight spacing distance and recommended range of skylight area?

Answer

The maximum spacing of skylights that results in the space being fully skylit is

Maximum skylight spacing = 1.4 x ceiling height + skylight width

Spacing skylights closer together results in more lighting uniformity and, thus, better lighting quality (at an increased cost because more skylights are needed). However, as a first ,approximation one can space the skylights by 1.4 times the ceiling height. For this example, skylights can be spaced 1.4 x 30 feet = 42 feet. In general, the design will also be dictated by the size of roof decking materials (such as 4′ by 8′ plywood decking) and the spacing of roof purlins so the edge of the skylights line up with roof purlins. For this example, we assume that roof deck material is 4′ by 8′ and skylights are spaced 40 feet on center.

Each skylight is serving a 40-foot by 40-foot area of 1,600 sq. ft. A standard skylight size for warehouses is often 4' by 8' (displacing one piece of roof decking). The ratio of skylight area to daylit area is 2 percent (32/1,600 = 0.02). Assuming this is a plastic skylight with a VT of 0.65, the product of skylight transmittance and skylight area to daylit area ratio is (0.65)(32/1,600) = 0.013 = 1.3 percent. An 8 ft. by 8 ft. skylight (two 4 ft. by 8 ft. skylights) installed on a 40-foot spacing would yield a 2.6 percent product of skylight transmittance and skylight area to daylit area ratio. With 64 square feet of skylight area for each 1,600 square feet of roof area, the skylight to roof area ratio is 4 percent, which is less than the maximum of 5 percent allowed by §140.3(a).

An alternate approach would be to space 4 ft. by 8 ft. skylights closer together, which would provide more uniform daylight distribution in the space and produce closer to the desired minimum VT skylight area product. Taking the product of the skylight VT and the skylight area and dividing by 0.02 (the desired ratio) yields the approximate area the skylight should serve. In this case, with a VT of 0.65 and a skylight area of 32 square feet, each skylight should serve around (0.65*32 /0.02) = 1,040 square feet. A 32-foot center to center spacing of skylights results in 32 x 32 = 1,024 square feet of daylit area per skylight.

For a 4 ft. by 8 ft. plastic skylight with a visible light transmittance of 0.65, the product of skylight transmittance and skylight area to daylit area ratio is

(0.65) x (32/1,024) = 0.0203 = 2.03 percent.

5.6 Prescriptive Compliance Approach for Indoor Lighting – Introduction

5.6.1 Requirements for a Compliant Building

A building complies with §140.6 if:

1. The adjusted indoor lighting power of all proposed building areas combined, when calculated in accordance with §140.6(a), is no greater than the allowed indoor lighting power, calculated in accordance with §140.6(c).
2. The calculation of allowed indoor lighting power meets the requirements in §140.6(b).

5.6.2 Calculation of Adjusted Indoor Lighting Power

The adjusted indoor lighting power of all building areas is the total watts of all planned permanent and portable lighting systems in the proposed building.

Some adjustments are available to reduce the reported indoor lighting power. These adjustments are discussed below.

A. Power Adjustment Factors or Reduction of Wattage Through Controls

The Energy Code provides an option for a lighting power reduction credit when specific lighting controls are installed, provided those lighting controls are not required.

A power adjustment factor (PAF) is an adjustment to the installed lighting power in an area that allows some of the installed lighting power to not be counted toward the building's total installed lighting load.

In calculating adjusted indoor lighting power, the installed watts of a luminaire providing general lighting in a functional area listed in Table 140.6-C may be reduced by multiplying the watts controlled by the applicable power adjustment PAF, per Table 140.6-A.

To qualify for a PAF, the following conditions must be met:

1. The person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices must sign and submit the certificate of installation before a PAF will be allowed for compliance with §140.6. If any of the requirements in this Certificate of Installation are not met, the installation shall not be eligible to use the PAF.
2. Luminaires and controls meet the applicable requirements of §110.9, and §130.0 through §130.5.
3. The controlled lighting is permanently installed general lighting systems and the controls are permanently installed nonresidential-rated lighting controls (portable lighting, portable lighting controls, and residential rated lighting controls do not qualify for PAFs).

   When used for determining PAFs for general lighting in offices, furniture-mounted luminaires shall qualify as permanently installed general lighting systems if:

   a. They are installed no later than the time of building permit inspection.
   b. They are permanently hardwired.
   c. They are designed to provide indirect general lighting. (They may also have elements that provide direct task lighting.)
   d. The lighting control for the furniture mounted luminaire complies with all other applicable requirements in §140.6(a)2.

   Before multiplying the installed watts of the furniture-mounted luminaire by the applicable PAF, 2 watts per square foot of the area illuminated by the furniture mounted luminaires shall be subtracted from installed watts of the furniture mounted luminaires to account for portable lighting.

4. At least 50 percent of the light output of the controlled luminaire is within the applicable area listed in Table 140.6-A. Luminaires on lighting tracks must be within the applicable area to qualify for a PAF.
5. Only one PAF from Table 140.6-A may be used for each qualifying luminaire. PAFs shall not be added together unless specifically allowed in Table 140.6-A.
6. Only lighting wattage directly controlled in accordance with §140.6(a)2 shall be used to reduce the calculated adjusted indoor lighting power as allowed by §140.6(a)2. If only a portion of the wattage in a luminaire is controlled in accordance with §140.6(a)2, then only that portion of controlled wattage may be reduced in calculating adjusted indoor lighting power.
7. Lighting controls used to qualify for a PAF shall be designed and installed in addition to manual, multilevel, and automatic lighting controls required in §130.1, and in addition to any other lighting controls required by the Energy Code.
8. To qualify for the PAF for daylight continuous dimming plus off control, the following requirements must be met:
   a. The daylight control and controlled luminaires must meet the requirements of §130.1(d), 130.4(a)3, and 130.4(a)7.
   b. The daylight control shall be continuous dimming and shall additionally turn lights completely off when the daylight available in the daylit zone is greater than 150 percent of the illuminance received from the general lighting system at full power.
   c. The PAF shall apply to the luminaires in the primary sidelit daylit zone, secondary sidelit daylit zone, and skylit daylit zone.
9. To qualify for the PAF for an occupant sensing control controlling the general lighting in large office areas above workstations, in accordance with Table 140.6-A, each occupant sensing control zone must be 250 square feet or smaller and the following requirements must be met (note that occupant sensing controls are already required in offices greater than 250 square feet per §130.1(c)6D, and each occupant sensing control zone may not be greater than 600 square feet (refer to Section 5.4.3 for more information); This PAF is provided when the occupant sensing control zones are 250 square feet or smaller):
   a. The office area must be greater than 250 square feet.
   b. This PAF is available only in office areas with workstations.
   c. Controlled luminaires may only be those that provide general lighting directly above the controlled area or furniture-mounted luminaires that comply with §140.6(a)2 and provide general lighting directly above the controlled area.
   d. Qualifying luminaires must be controlled by occupant sensing controls that meet the following requirements, as applicable:

i. Infrared sensors shall be equipped (either by the manufacturer or in the field by the installer) with lenses or shrouds to prevent them from being triggered by movement outside the controlled area.

ii. Ultrasonic sensors shall be tuned to reduce their sensitivity, to prevent them from being triggered by movements outside the controlled area.

iii. All other sensors shall be installed and adjusted as necessary to prevent them from being triggered by movements outside the controlled area.

e. The PAF shall be applied only to the portion of the installed lighting power that is controlled by the occupant sensors, not to the total installed lighting power.

f. The value of the PAF (0.2 or 0.3) depends on the square footage controlled by each occupant sensor.

10. The following requirements must be met to qualify for the institutional tuning PAF:

a. The lighting controls must limit the maximum output or maximum power draw of the controlled lighting to 85 percent or less of full light output or full power draw.

b. The means of setting the limit must be accessible only to authorized personnel.

c. The setting of the limit must be verified by the acceptance test required by §130.4(a)7.

d. The construction documents must specify which lighting systems will have their maximum light output or maximum power draw set to no greater than 85 percent of full light output or full power draw.

11. To qualify for the Demand Responsive Control PAF, the general lighting wattage receiving the PAF must not be within the scope of §110.12(c) and the following requirements must be met:

a. The controlled lighting must be capable of being automatically reduced in response to a demand response signal.

b. General lighting must be reduced in a manner consistent with the uniform level of illumination requirements in Table 130.1-A.

Requirements of §110.12(c): Buildings with nonresidential lighting systems having a total installed lighting power of 4,000 watts or greater that is subject to the requirements of §130.1(b) shall install controls capable of automatically reducing lighting power in response to a Demand Response Signal. See Section 5.4.5 of this manual for more information.

12. To qualify for the PAF for daylighting devices (including clerestories, light shelves, and horizontal slats) in Table 140.6-A, the daylighting devices must meet the requirements in §140.3(d). The PAFs shall only apply to lighting in a

primary or secondary sidelit daylit zone where continuous dimming daylighting controls meeting the requirements of §130.1(d) are installed.

Refer to Chapter 3 for more information on the requirements for daylighting devices that qualify for a PAF.

B. Luminaire Power Adjustment

Color-tunable LED lighting technologies are available for lighting applications including hospitality, healthcare, and other uses. This technology produces correlated color temperatures (CCT) that match the current use of a space.

Two categories of color tunable luminaires – tunable-white LED and dim-to-warm LED luminaires – can qualify for a luminaire lighting power adjustment multiplier of 0.80 if the luminaire meet all of the requirements of §140.6(a)4B, paragraphed below:

- Small Aperture: Luminaire aperture width no wider than 4 inches for an aperture length longer than 18 inches; aperture width no wider than 8 inches otherwise.
- Color Changing Capability: Capable of color change greater than or equal to 2000K CCT for tunable-white LED luminaires; capable of color change greater than or equal to 500K CCT for dim-to-warm LED luminaires.
- Controls: Connected to controls that allow color changing of the illumination.

Figure 5-21: Example of Dim-to-Warm Lighting: An Indoor Space With Dim-to-Warm Luminaires (top); Relationship of Dimming to Change in Correlated Color Temperature of Dim-to-Warm (aka "WarmDim") Lighting Technology (bottom image)

Image Source: NORA Lighting

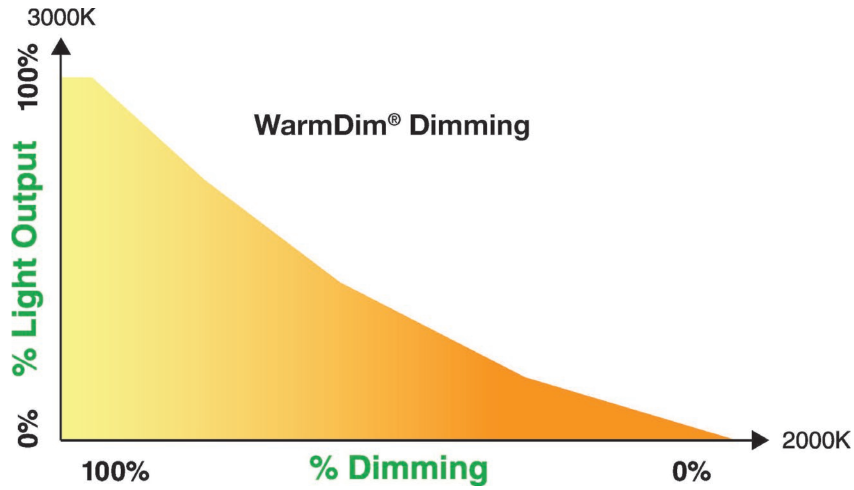


Image Source: Juno WarmDimming® Dimming courtesy of Acuity Brands Lighting, Inc.

C. Portable Lighting in Office Areas

Section 140.6(a) of the Energy Code requires that all planned lighting, including portable and permanent lighting systems, be counted toward the lighting energy use of the building, regardless of when it is planned to be installed.

Because office cubicles (including their portable lighting) are typically not installed until after the building inspection is complete, the portable lighting power is counted together with the permanent lighting as the adjusted lighting power for compliance. When using the area category method for offices with portable lighting, the additional lighting power provision is available for portable lighting and decorative/display lighting. Refer to Section 5.7.3 for more information about the area category method.

The Energy Code defines portable lighting as lighting with plug-in connections for electric power. That includes table and floor lamps, those attached to modular furniture, workstation task luminaires, luminaires attached to workstation panels, those attached to movable displays, or those attached to personal property.

D. Two Interlocked Lighting Systems

Within the following five functional areas, as defined in §100.1, two lighting systems may be installed provided they are interlocked so that both lighting systems cannot operate simultaneously. All other functional areas are permitted to install only one lighting system.

1. Auditorium
2. Convention center
3. Conference room
4. Multipurpose room
5. Theater

No more than two lighting systems may be used for these five specifically defined functional areas, and if there are two lighting systems, they must be interlocked.

Where there are two interlocked lighting systems, the lower-wattage system may be excluded from determining the adjusted indoor lighting power if:

1. The person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices must sign and submit the certificate of installation before two interlocked lighting systems will be recognized for compliance.
2. If any of the requirements in the certificate of installation are not met, the two interlocked lighting systems will not be recognized for compliance.
3. The two lighting systems shall be interlocked with a nonprogrammable double-throw switch to prevent simultaneous operation of both systems.

   For compliance with the Energy Code, a nonprogrammable double-throw switch is an electrical switch commonly called a "single pole double throw" or "three-way" switch that is wired as a selector switch allowing one of two loads to be enabled. It can be a line voltage switch or a low-voltage switch selecting between two relays. It cannot be overridden or changed in any manner that would permit both loads to operate simultaneously.

E. Lighting Wattage Not Counted Toward Building Load

The Energy Code does not require the lighting power of certain types of luminaires in specific functional areas, or for specific purposes, to be counted toward the installed lighting power of a building. For example, lighting in the guest rooms of hotels is not required to be counted for compliance with §140.6. However, lighting in all other function areas within a hotel are required to comply with all applicable requirements in §140.6. Lighting in guest rooms is, however, regulated by the low-rise residential lighting standards.

The wattage of the following indoor lighting applications may be excluded from the adjusted (installed) indoor lighting power:

- Lighting for themes and special effects in theme parks.
- Studio lighting for film or photography provided that these lighting systems are in addition to and separately switched from a general lighting system.
- Lighting for dance floors, theatrical and other live performances, and religious worship provided that these lighting systems are in addition to a general lighting system and are separately controlled by a multiscene or theatrical cross-fade control station accessible only to authorized operators.
- Lighting intended for makeup, hair, and costume preparation in performance arts facility dressing rooms if the lighting is switched separately from the general lighting system, switched independently at each dressing station, and controlled with a vacancy sensor.

- Lighting for temporary exhibits in civic facilities, transportation facilities, convention centers, and hotel function areas if the lighting is an addition to a general lighting system and is separately controlled from a panel accessible only to authorized operators.
- Lighting installed by the manufacturer in walk-in freezers, vending machines, food preparation equipment, and scientific and industrial equipment.
- Examination and surgical lights, low-ambient night-lights, and lighting integral to medical equipment, if this lighting is in addition to and switched separately from a general lighting system.
- Lighting for plant growth or maintenance in non-controlled environment horticulture spaces, if it is controlled by a multilevel astronomical time-switch control that complies with the applicable provisions of §110.9.
- Lighting equipment that is for sale.
- Lighting demonstration equipment in lighting education facilities.
- Lighting that is required for exit signs subject to the CBC. Exit signs shall meet the requirements of the Appliance Efficiency Regulations.
- Exit way or egress illumination that is normally off and that is subject to the CBC.
- In hotel/motel buildings: Lighting in guest rooms (lighting in hotel/motel guest rooms must comply with §130.0(b). (Indoor lighting not in guest rooms must be in compliance with all applicable nonresidential lighting requirements in the Energy Code.)
- Temporary lighting systems. Temporary lighting is defined as a lighting installation with plug-in connections that does not persist beyond 60 consecutive days or more than 120 days per year.
- Lighting in Occupancy Group U buildings smaller than 1,000 sq. ft.
- Lighting in unconditioned agricultural buildings smaller than 2,500 sq. ft.
- Lighting systems in qualified historic buildings, as defined in the State Historic Building Code (Title 24, Part 8), are exempt from the lighting power allowances if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems in qualified buildings contain some historic lighting components or replicas of historic components, combined with other lighting components, only those historic or replica components are exempt. All other lighting systems in qualified historic buildings shall comply with the lighting power allowances.
- Lighting in nonresidential parking garages for seven or fewer vehicles must comply with the applicable residential parking garage provisions of §150.0(k).
- Lighting for signs must comply with §140.8.

- Lighting in refrigerated cases smaller than 3,000 sq ft. must comply with the Appliance Efficiency Regulations.
- Lighting in elevators meeting the requirements in §120.6(f).
- Lighting connected to a life safety branch or critical branch, as specified in Section 517 of the California Electrical Code.
- Horticultural lighting in Controlled Environment Horticulture (CEH) spaces (indoor growing and greenhouses) complying with Section 120.6(h).

Nonresidential indoor lighting applications not listed above must comply with all applicable nonresidential indoor lighting requirements.

Example 5-17: Lighting Power Exceptions and Control Requirements

Question

For indoor lighting, if lighting is excluded from the indoor power limitations per §140.6(a)3, is that lighting also excluded from the indoor lighting control requirements of §130.1?

Answer

No. Indoor lighting excluded from the power limitations of §140.6 is not necessarily exempt from the mandatory control requirements of §130.1. These sections are independent of each other.

5.7 Prescriptive Compliance Approach for Indoor Lighting — Allowed Indoor Lighting Power

5.7.1 General Rules for Calculation of Allowed Indoor Lighting Power

§140.6(b)

The Energy Code limits the amount of lighting power that may be installed in a building. The following are the general rules for calculating allowed indoor lighting power.

1. There shall be no lighting power allotment trade-offs between the separate conditioned and unconditioned indoor function areas. Indoor conditioned and indoor unconditioned lighting power allotments must each be separately determined on compliance documentation.
2. There shall be no lighting power allotment trade-offs between the separate indoor and outdoor function areas. Indoor and outdoor lighting power allotments must each be separately determined on compliance documentation.
3. Some areas of a building may use the Tailored Method, while other areas of the same building may use the Area Category Method. However, no single area

in a building shall be allowed to use both the Tailored Method and the Area Category Method.

4. The Tailored Method shall not be used in any building using the Complete Building method for compliance.

5.7.2 Complete Building Method (One of the Three Prescriptive Compliance Approaches)

§140.6(c)1

The Complete Building Method shall only be applied when lighting will be installed throughout the entire building. The building must consist of one type of use for a minimum of 90 percent of the floor area of the entire building.

The allowed indoor lighting power allotment for the entire building shall be calculated as follows:

1. For a conditioned building, multiply the entire conditioned floor area of the building by the applicable lighting power density (LPD, watts per sq. ft.) provided in Table 140.6-B.
2. For an unconditioned building, multiply the entire unconditioned floor area of the building by the applicable LPD provided in Table 140.6-B.

5.7.2.1 Requirements for Using the Complete Building Method

The Complete Building Method shall be used only for building types, as defined in §100.1, that are specifically listed in Table 140.6-B (for example, retail store buildings and office buildings.)

The Complete Building Method shall be used only on projects involving:

a. Entire buildings with one type of use occupancy.
b. Mixed occupancy buildings where one type of use makes up at least 90 percent of the entire building (in which case, when applying the Complete Building Method, it shall be assumed that the primary use is 100 percent of the building).
c. A tenant space where one type of use makes up at least 90 percent of the entire tenant space (in which case, when applying the Complete Building Method, it shall be assumed that the primary use is 100 percent of the tenant space).

A few more notes as follows:

- Use the Complete Building Method only when the applicant is applying for a lighting permit and submits plans and specifications for the entire building or the entire tenant space.

- Use the Complete Building Method only when the lighting power allotment in Table 140.6-B is available for the entire building. There are no additional lighting power allowances available when using Complete Building Method. Also, there are no mounting height multipliers available when using the Complete Building Method.
- For buildings including a parking garage plus another type of use listed in Table 140.6-B, the parking garage portion of the building and other type of use portion of the building shall each separately use the Complete Building Method.

Example 5-18: Mixed-Occupancy Parking Garage Building

Question

A building is to be constructed with 95 percent of it consisting of a parking garage, and the remaining 5 percent consisting of offices and support spaces such as an electrical room. What is the assumed building type under the complete building method?

Answer

Since parking garage makes up at least 90 percent of the entire building, the building shall be considered a parking garage when applying the Complete Building Method.

5.7.2.2 Definitions of Complete Building Types

When using the Complete Building Method, qualifying building types are those in which a minimum of 90 percent of the building floor area functions as one of the building types listed in Table 140.6-B, (as defined below), and which do not qualify as any other building occupancy type more specifically defined in §100.1 (the occupancy type information are provided below), and which do not have a combined total of more than 10 percent of the area functioning as any nonresidential function areas specifically defined in §100.1.

Definitions of Nonresidential Building Occupancy Types (Below are partial list from §100.1):

Assembly Building is a building with meeting halls in which people gather for civic, social, or recreational activities. These include civic centers, convention centers and auditoriums.

Grocery Store Building is a building with building floor areas used for the display and sale of food.

Gymnasium Building is a building with building floor areas used for physical exercises and recreational sport events and activities.

Healthcare Facility is any building or portion thereof licensed pursuant to California Health and Safety Code Division 2, Chapter 1, section 1204 or Chapter 2, section 1250.

Industrial/Manufacturing Facility Building is a building with building floor areas used for performing a craft, assembly, or manufacturing operation.

Office Building is a building of CBC Group B Occupancy with building floor areas in which business, clerical or professional activities are conducted.

Parking Garage Building is a building with building floor areas used for parking vehicles and consists of at least a roof over the parking area enclosed with walls on all sides. The building includes areas for vehicle maneuvering to reach designated parking spaces. If the roof of a parking structure is also used for parking, the section without an overhead roof is considered an outdoor parking lot instead of a parking garage.

Religious Facility Building is a building with building floor areas used for assembly of people to worship.

Restaurant Building is a building with building floor areas in which food and drink are prepared and served to customers in return for money.

Retail Store Building is a building with building floor areas used for the display and sale of merchandise except food.

School Building is a building used by an educational institution. The building floor area can include classrooms or educational laboratories, and may include an auditorium, gymnasium, kitchen, library, multipurpose room, cafeteria, student union, or workroom. A maintenance or storage building is not a school building.

5.7.3 Area Category Method (One of the Prescriptive Compliance Approaches)

§140.6(c)2

5.7.3.1 Area Category Method General Lighting Power Allotment

The Area Category Method is more flexible than the Complete Building Method because it can be used for multiple tenants or partially completed buildings. Under the Area Category Method, an "area" is defined as all contiguous spaces that accommodate or are associated with a single primary function as listed in Table 140.6-C. For primary function areas not listed, selection of a reasonably equivalent type shall be permitted. When the lighting in these areas is completed later under a new permit, the applicant may show compliance with any of the lighting options except the Complete Building Method.

The Area Category Method divides a building into primary function areas. Each function area is defined in §100.1. The allowed lighting power is determined by multiplying the area of each function times the lighting power density for that function. Where areas are bounded or separated by interior partitions, the floor space occupied by those interior partitions shall be included in any area. The total allowed watts are the summation of the allowed lighting power for each area covered by the permit application.

When using this method, each function area in the building must be included as a separate area. Boundaries between primary function areas may or may not consist of walls or partitions. For example, kitchen and dining areas within a fast food restaurant may or may not be separated by walls. For purposes of compliance, they must still be separated into two different function areas. However, it is not necessary to separate aisles or entries within primary function areas. When the Area Category Method is used to calculate the allowed total lighting power for an entire building however, the main entry lobbies, corridors, restrooms, and support functions shall each be treated as separate function areas.

Requirements for using the Area Category Method include all of the following:

1. The Area Category Method shall be used only for primary function areas, as defined in §100.1, that are listed in Table 140.6-C.
2. Primary Function Areas in Table 140.6-C shall not apply to a complete building. Each primary function area shall be determined as a separate area.
3. For purposes of compliance with §140.6(c)2, an "area" shall be defined as all contiguous areas which accommodate or are associated with a single primary function area listed in Table 146.0-C.
4. Where areas are bounded or separated by interior partitions, the floor area occupied by those interior partitions may be included in a Primary Function Area.
5. If at the time of permitting for a newly constructed building, a tenant is not identified for a multitenant area, a maximum of 0.4 watts per sq. ft. shall be allowed for the lighting in each area in which a tenant has not been identified. The area shall be classified as Unleased Tenant Area.
6. Under the Area Category Method, the allowed indoor lighting power for each primary function area is the lighting power density value in Table 140.6-C multiplied by the square footage of the primary function area. The total allowed indoor lighting power for the building is the sum of the allowed indoor lighting power for all areas in the building.

5.7.3.2 Additional Lighting Power — Area Category Method

In addition to the allowed indoor lighting power calculated according to §140.6-B through F, the building may add additional lighting power allowances for qualifying lighting systems as specified in the Qualifying Lighting Systems column in Table 140.6-C under the following conditions:

1. Only primary function areas having a lighting system as specified in the Qualifying Lighting Systems column in Table 140.6-C and in accordance with

the corresponding footnote of the table shall qualify for the additional lighting power allowances.

2. The additional lighting power allowances shall be used only if the plans clearly identify all applicable task areas and the lighting equipment designed to illuminate these tasks.
3. Tasks that are performed less than two hours per day or poor-quality tasks that can be improved are not eligible for the additional lighting power allowances.
4. The additional lighting power allowances shall not utilize any type of luminaires that are used for general lighting in the building.
5. The additional lighting power allowances are used only for areas complying with the Area Category Method. The allowances shall not be used when using the Complete Building Method or when the Tailored Method is used for an area in the building.
6. The additional lighting power allowed is the smaller of:
   i. The lighting power density listed in the "Allowed Additional Lighting LPD" column in Table 140.6-C, times the sq. ft. of the primary function, or
   ii. The adjusted indoor lighting power of the applicable lighting.
7. In addition to meeting §140.6(c)2Gi through vi, additional lighting power for videoconferencing as specified in Table 140.6-C shall be allowed in a videoconferencing studio, as defined in §100.1, provided the following conditions are met:
   i. Before the Additional Videoconference Studio Lighting power allotment will be allowed for compliance with §140.6 of the Energy Code, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the certificate of installation.

      If any of the requirements in this certificate of installation are not met, the Additional Videoconference Studio Lighting installation shall not be eligible for the additional lighting power allotment.
   ii. The Videoconferencing Studio is a room with permanently installed videoconferencing cameras, audio equipment, and playback equipment for both audio-based and video-based two-way communication between local and remote sites.
   iii. General lighting is controlled in accordance with Table 130.1-A.
   iv. Wall wash lighting is separately switched from the general lighting system.

v. All of the lighting in the studio, including general lighting and additional lighting power allowed by §140.6(c)2Gvii is controlled by a multi-scene programmable control system (also known as a scene preset control system).

Lighting Terms:

(related to both Area Category Method and Tailored Method)

Accent Lighting is directional lighting to emphasize a particular object or surface feature, or to draw attention to a part of the field of view. It can be recessed, surface mounted, or mounted to a pendant, stem, or track, and can be display lighting. It shall not provide general lighting.

Decorative Lighting/Luminaires is lighting or luminaires installed only for aesthetic purposes and that does not serve as display lighting or general lighting. Decorative luminaires are chandeliers, sconces, lanterns, neon or cold cathode, light emitting diodes, theatrical projectors, moving lights, and light color panels, not providing general lighting or task lighting.

Dim-to-warm (also known as warm dim) light source is capable of simultaneously decreasing its correlated color temperature as its light output decreases, typically resembling the change in color temperature of an incandescent lamp as it dims.

Floor Display Lighting is supplementary lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance required to highlight features, such as merchandise on a clothing rack or sculpture or free standing of artwork, which is not displayed against a wall.

General Lighting is installed electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect, exclusive of daylighting, and also known as ambient lighting.

Special Effects Lighting is lighting installed to give off luminance instead of providing illuminance, which does not serve as general, task, or display lighting.

Tunable white light source is capable of adjusting its correlated color temperature while maintaining its relative light output and capable of adjusting its light output while maintaining its correlated color temperature.

Wall Display Lighting is supplementary lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance required to highlight features, such as merchandise on a shelf or wall-mounted artwork, which is displayed on perimeter walls.

Window Display Lighting is lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance of objects such as merchandise, goods, and artifacts, in a show window, to be viewed from the outside of a space through a window.

Example 5-19: Lighting Power Allowance for Special Effect Lighting and Non-General Lighting

There is lighting power allowance for special effects lighting in the Decorative/Special Effects Lighting additional power allowance in the tailored method to lighting power compliance in Table 140.6-D where both terms are combined.

Both the area category method (Table 140.6-C) and the tailored method (table 140.6-D) provide additional lighting power allowances for lighting that is not considered general lighting; however, to claim these allowances, the other lighting systems must be separately switched.

Under layered lighting design scenarios with multiple luminaire types, compliance documentation will require allocating some or all of non-general lighting power to the additional lighting power allowances and the rest of the lighting wattage to the general lighting power allowance. Only the general lighting power allowance is able to be shared across different spaces.

When there is only one lighting system type in a space, such as is the case when a monolithic design approach is taken, that system type will be treated as general lighting. Thus, light fixtures that might ordinarily be considered ornamental or display luminaires are considered general lighting luminaires if they are the only system type in a given enclosed space.

Example 5-20: Corridor With Accent Lighting and General Lighting

A corridor may have a lighting system to provide both accent lighting and general lighting as illustrated in the following images about three different corridor scenarios.

Figure 5-22: Corridors With Accent Lighting and General Lighting: A Corridor With Wall Washer and Accent Luminaires (left image), a

Corridor With Recessed Troffer Luminaires (center image), and a Corridor With Scone Luminaires (right image)

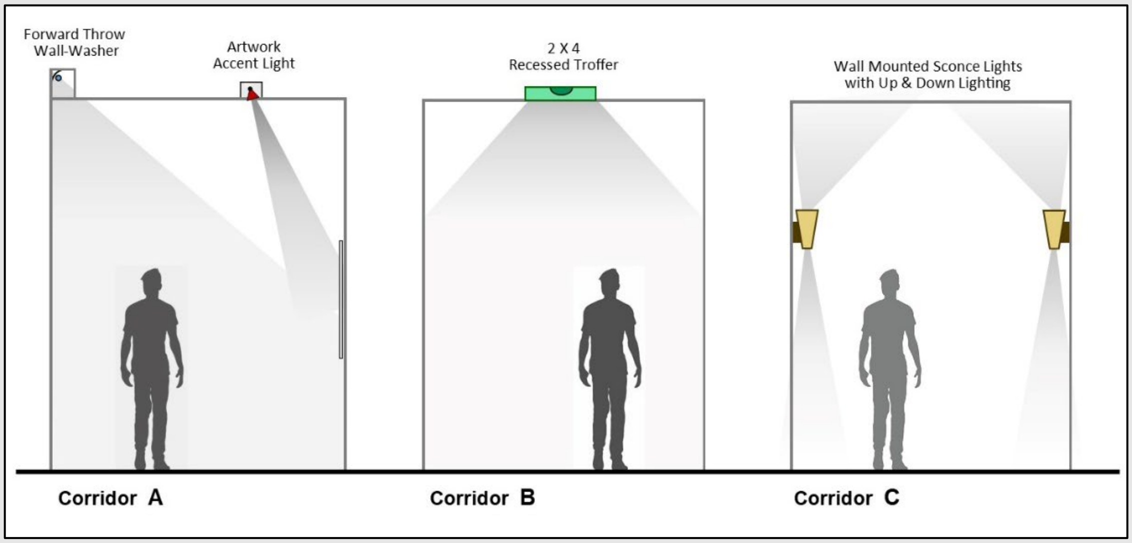


Image Source: Bernie Bauer

Corridor A has two lighting systems: forward wall-washers which provides the primary illumination and recessed accent lights for highlighting artwork. Wall-washers (asymmetric optics) are generally used as accent or feature lighting. However, in this scenario since they provide the general or ambient illumination the lighting power for these luminaires per Table 140.6-C Area Category Method are allowed up to the 0.40 W per sq. ft general lighting allowance for corridor spaces. The artwork recessed accent lights are providing focal illumination to highlight the art. Therefore, the lighting power for these luminaires may be assigned to the 0.25 W per sq. ft. decorative/display lighting allowance listed under the “Additional Lighting Power” column of Table 140.6-C.

One option: provided the total lighting power of the wall-washers and accent lights is equal to or less than the allowed 0.4 W per sq. ft. general lighting power allowance for corridor spaces under Table 140.6-C, both luminaires may use the general lighting power allowance.

Another option: if the total lighting power of the wall-washers and accent lights exceeds the 0.4 W per sq. ft. general lighting power allowance for corridor spaces under Table 140.6-C, an additional 0.25 W per sq. ft. decorative/display lighting allowance may be used for the accent lights provided that the accent lights are separately switched from the wall washers. The additional lighting power allowed will be the lower of the calculated additional allowance for decorative/display lighting or the proposed wattage of the accent lighting.

Corridor B has one lighting system (2 by 4 recessed LED basket troffers) which provides all the illumination for the space. Basket troffers (symmetric wide distribution optics) are primarily to provide general or ambient illumination. Therefore, the lighting power for these luminaires must be assigned to the 0.4 W per sq. ft. general lighting power allowance for corridor spaces listed in Table 140.6-C. The 0.25 W per sq. ft. decorative/display lighting allowance does not apply in this scenario as there are no luminaires providing directional illumination.

Corridor C has one lighting system: wall sconces that provide up-lighting on the ceiling for general /ambient illumination, but the sconces also include a downlight element. However, in this scenario since they provide the general or ambient illumination the lighting power for these luminaires are assigned the 0.40 W per sq. ft. general lighting power allowance for corridor spaces as listed in Table 140.6-C. If needed, the 0.25 W per sq. ft. decorative/display lighting allowance could also apply in this scenario. However, the up-light and downlight components of the luminaries must be placed on separate circuits.

Example 5-21: Calculating the Allowed Lighting Power Using Area Category Method

Question

What is the allowed lighting power for a 10,000-ft² multi-use building with the following area types?

- Main entry lobby of 500 ft²,
- Corridors of 1,500 ft²,
- Grocery store (Grocery Sales) of 3,000 ft²,
- Retail store (Retail Merchandise Sales) of 2,500 ft²
- Restrooms of 500 ft²
- Future development of 2,000 ft²

Answer

Most of the functional area types and corresponding lighting power density values can be found in Table 140.6-C. The future development area type is unknown with no built-out plan at the time of permitting, therefore the function area type is designated as “All other” with LPD of 0.4 W/ft².

	Area	LPD	Size in ft²	Allowed Lighting Power
1)	Main Entry	0.7 W/ft²	500 ft²	350 W
2)	Corridors	0.4 W/ft²	1,500 ft²	600 W
3)	Grocery Store (Grocery Sales)	1 W/ft²	3,000 ft²	3,000 W
4)	Retail Store (Merchandise Sales)	0.95 W/ft²	2,500 ft²	2,375 W
5)	Restrooms	0.65 W/ft²	500 ft²	325 W
6)	Future Development (All other)	0.4 W/ft²	2,000 ft²	800 W
	TOTAL		10,000 ft²	7,450 watts

Example 5-22: Tunable-White and Dim-to-Warm Luminaires

Question

Which tunable-white and dim-to-warm luminaires qualify for the additional lighting power allowance for applications in healthcare facilities?

Answer

There is additional lighting power allowance for tunable-white and dim-to-warm luminaires for most of the healthcare/hospital function areas as specified in Table 140.6-C.

The qualified tunable-white luminaires shall be capable of color change ≥ 2000K CCT.

The qualified dim-to-warm luminaires shall be capable of color change ≥ 500K CCT.

A dim-to-warm luminaire product capable of color tune from 2700K to 1800K is acceptable and qualifies for the additional light power.

5.7.4 Tailored Method (One of the Prescriptive Compliance Approaches)

§140.6(c)3

5.7.4.1 Tailored Method Application

The Tailored Method is a lighting compliance approach which establishes an allowed lighting power budget on a room-by-room or area-by-area basis.

Use of tailored method could be helpful when more general lighting power is required for the listed primary function areas[2] in Table 140.6-D that have a high room cavity ratio (RCR).

In addition to providing a lighting power budget for general illumination, the tailored method provides additional lighting power budgets for illuminating wall displays, floor displays, task lighting, and decorative/special effects lighting. These additional layers of lighting power have been informally referred to as "use-it-or-lose-it" lighting power allowances because these additional allowances cannot be traded-off to other areas or applications. If a lighting design does not include these additional layers of lighting power, the total lighting power budget using the Tailored Method may be less than if the Area Category Method or Complete Building Method of compliance is used.

5.7.4.2 Determining Allowed General Lighting Power Using the Tailored Method

§140.6(c)3G thru 3H; Table 140.6-D, F, G

A. Tailored Method Trade-Off Allowances

Compliance tools such as compliance software programs can be used to document trading-off Tailored Method lighting power allotments. Trade-offs are available only for general lighting and only under the following circumstances:

1. From one conditioned primary function area using the Tailored Method, to another conditioned primary function area using the Tailored Method.
2. From one conditioned primary function area using the Tailored Method, to another conditioned primary function area using the Area Category Method.
3. From one unconditioned primary function area using the Tailored Method, to another unconditioned primary function area using the Tailored Method.
4. From one unconditioned primary function area using the Tailored Method, to another unconditioned primary function area using the Area Category Method.

A. Calculating Tailored Method General Lighting Power Allotments

The Energy Code defines general lighting as installed electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect, exclusive of daylighting. To qualify as

2 Definitions of the primary function areas can be found in §100.1.

general lighting for the Tailored Method, the lighting system shall not use narrow beam direction lamps, wall-washers, valance, direct cove, or perimeter linear slot types of lighting systems.

Section 140.6(c)3F shall be used to determine the general lighting power density allotments as follows:

1. **Using Table 140.6-D and 140.6-G to Determine General Lighting Power Allotments:**
   a. Find the appropriate Primary Function Area in column 1 of Table 140.6-D that fits one of the Nonresidential Function Area definitions in §100.1.
   b. Find the corresponding General Illumination Level (Lux) in column 2.
   c. Determine the room cavity ratio (RCR) for that primary function area, according to the applicable equation in Table 140.6-F. Use the nonresidential certificate of compliance to document the RCR calculation.
   d. Refer to Table 140.6-G, using the General Illumination Level (Lux, determined according to item b), and the RCR (determined according to item c), to determine the allowed general lighting power density value.
   e. Multiply the allowed general lighting power density value by the square footage of the primary function area. The product is the allowed general lighting power for general lighting for that primary function area.
2. **How to calculate Room Cavity Ratio (RCR)**
   - The room cavity ratio must be determined for any primary function area using the Tailored Lighting Method.
   - The lighting level in a room is affected in part by the configuration of the room, expressed as the room cavity ratio (RCR). Rooms with relatively high ceilings typically are more difficult to light and have a high RCR. Because luminaires are not as effective in a room with a high RCR, §140.6 allows a greater LPD to compensate for this effect.
   - The RCR is based on the entire space bounded by floor-to-ceiling partitions. If a task area within a larger space is not bounded by floor to ceiling partitions, the RCR of the entire space must be used for the task area. The exception to this rule allows for imaginary or virtual walls when the boundaries are established by "high stack" elements (close to the ceiling structure and high storage shelves) or high partial walls defined as "permanent full height partitions" described in §140.6(c)3Giii wall display. These permanent full height partitions are only applicable when claiming additional lighting power for wall display lighting.
   - The RCR is calculated from one of the following formulas:

Equation 5-3 (Table 140.6-F) Rectangular Shaped Rooms

$$RCR = \frac{5 \times H \times (L + W)}{A}$$

Where:

RCR = The room cavity ratio

H = The room cavity height, vertical distance measured from the work plane to the center line of the luminaire

L = The room length using interior dimensions

W = The room width using interior dimensions

A = The room area (L x W)

Equation 5-4 (Table 140.6-F) Non-Rectangular Shaped Rooms

$$RCR = \frac{[2.5 \times H \times P]}{A}$$

Where:

RCR = The room cavity ratio

H = The room cavity height (see equation above)

A = The room area

P = The room perimeter length

- For rectangular rooms, these two methods yield the same result and the second more general form of calculating RCR may be used in all instances, if desirable.
- It is not necessary to document RCR values for rooms with an RCR less than 2.0. Rooms with a RCR higher than 2.0 are allowed higher LPDs under the Tailored Method.
- A special situation occurs when illuminating stacks of shelves in libraries, warehouses, and similar spaces. In this situation, the lighting requirements are to illuminate the vertical stack rather than the horizontal floor area. In stack areas the RCR is assumed to be greater than seven. The non-stack areas are treated normally.

Example 5-23: Calculating Room Cavity Ratio (RCR)

Question

A small retail shop "Personal Shopper" room is 14 ft. wide by 20 ft. long by 8 ft. high. The lighting system uses recessed ceiling fixtures. The task surface is at desk height (2.5 ft. above the floor). What is the room cavity ratio?

Answer

The room cavity height is the distance from the ceiling (center line of luminaires) to the task surface (desk height). This is 8 ft. -2.5 ft. = 5.5 ft.

RCR = 5 x H x (L + W) / Area

RCR = 5 x 5.5 (14+20) / (14 x 20) = 3.34

5.7.4.3 Additional Lighting Power – Tailored Method

§140.6(c)3G thru 3J; Table 140.6-D and E

When using the Tailored Method for lighting compliance, there are additional lighting power allowances for the following lighting applications:

- Wall display lighting
- Floor display lighting and task lighting
- Decorative/special effects lighting
- Very valuable display case lighting

The additional lighting power values and adjustment factor values are listed in Table 140.6-D, E, F, and G. These additional layers of lighting power are not available when using §140.6(c)3F to determine the general Lighting Power allotment and are not available for any primary function areas using the Complete Building or Area Category methods of compliance.

All of the additional lighting power allowances are "use-it-or-lose-it" allowances that cannot be traded-off. That is, if the installed watts are less than the allowed watts, the difference in watts is not available to trade off anywhere else in the building.

Use the appropriate compliance form to document the additional lighting power for wall display lighting, floor display lighting and task lighting, decorative/special effects lighting, and very valuable display case lighting.

Lighting Terms:

(related to Tailored Method and Area Category Method)

Floor Display Lighting is supplementary lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance required to highlight features, such as merchandise on a clothing rack or sculpture or free standing of artwork, which is not displayed against a wall.

Wall Display Lighting is supplementary lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance required to highlight features, such as merchandise on a shelf or wall-mounted artwork, which is displayed on perimeter walls.

Display Case Lighting is lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance of small art objects, artifacts, or valuable collections which involves customer inspection of very fine detail from outside of a glass enclosed display case.
Task Lighting is lighting directed to a specific surface or area, providing illumination for visual tasks. Task lighting is not general lighting.

B. Additional Wall Display Lighting Power

Wall display lighting is defined as supplementary lighting required to highlight features such as merchandise on a shelf or other wall features such as graphics, artwork, or product presentation; and that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance.

Additional allowed power for wall display lighting is available only for lighting that illuminates walls having wall displays or wall features, and only when there is a watt per linear foot allowance in column 3 of Table 140.6-D for the primary function area.

1. The additional allowed power for wall display lighting shall be the smaller of:
   i. The wall display lighting power density values (column 3 of Table 140.6-D) multiplied by the wall display length.
   ii. The adjusted lighting power used for the wall display luminaires.

   Calculate the adjusted lighting power by multiplying the maximum rated wattage of the wall display luminaires with the appropriate mounting height adjustment factor from Table 140.6-E.

   Note that mounting height adjustment factor is available for wall display luminaires mounted greater than 10 feet 6 inches from the finished floor. Mounting height is the distance from the finished floor to the bottom of the luminaire.
2. To qualify for the additional wall display lighting power:
   i. The lighting system shall be a type that is appropriate for creating a higher level of illuminance on the wall display. Lighting systems appropriate for wall display lighting are lighting track adjacent to the wall, wall-washer luminaires, luminaires behind a wall valance or wall cove, or accent light. (Accent luminaires are adjustable or fixed luminaires with PAR, R, MR, AR, or luminaires providing directional display lighting.)
   ii. The qualifying wall display lighting shall be mounted within 10 feet of the wall having the wall display.
   iii. The lighting system shall not be a general lighting system type.

   Note: Lighting internal to display cases that are attached to a wall or directly adjacent to a wall are counted as wall display. All other lighting internal to display cases are counted as floor display lighting, or as very valuable display case lighting.

3. The length of display walls shall include the length of the perimeter walls including but not limited to closable openings and permanent full height interior partitions.

   Permanent full height interior partitions are those that meet the following conditions:

   i. Extend from the floor to within two feet of the ceiling or are taller than ten feet; and
   ii. Are permanently anchored to the floor.

4. The additional wall display lighting power is not available for the following:

   i. For any function areas using the Complete Building or Area Category methods of compliance.
   ii. General lighting systems.

   Note that floor displays shall not qualify for wall display lighting power allowances.

C. Additional Floor Display and Task Lighting Power

Floor display lighting is defined as supplementary lighting required to highlight features, such as merchandise on a clothing rack or floor mounted artwork and featured architectural elements, which are not displayed against a wall. Floor display lighting provides a higher level of illuminance to this specific area than the level of surrounding ambient illuminance.

Task Lighting is defined as lighting that specifically illuminates a location where a task is performed, but not general lighting.

Additional allowed power for floor display lighting and additional allowed power for task lighting may be used only for qualifying floor display lighting systems, qualifying task lighting systems, or a combination of both, for the listed primary function areas in Table 140.6-D.

Lighting internal to display cases that are not attached to a wall and not directly adjacent to a wall, shall be counted as floor display lighting or very valuable display case lighting.

1. The additional allowed power for the floor display and task lighting shall be the smaller of:

   a. The floor display and task lighting power density values (column 4 of Table 140.6-D) multiplied by the square footage of floor display or task area.
   b. The adjusted lighting power used for floor display lighting or task lighting.

Calculate the adjusted lighting power by multiplying the maximum rated wattage of the floor display or task luminaires with the appropriate mounting height adjustment factor from Table 140.6-E.

Note that mounting height adjustment factor is available for floor display luminaires mounted greater than 10 feet, 6 inches from the finished floor. Mounting height is the distance from the finished floor to the bottom of the luminaire.

2. To qualify for additional floor display lighting power:
   a. The floor display lighting system shall be mounted no closer than 2 feet to a wall. When track lighting is used for floor display lighting, and where portions of that lighting track are more than 2 feet from the wall and other portions are within 2 feet of the wall, only those portions of track more than 2 feet from the wall shall qualify for the floor display lighting power allowance.
   b. The floor display lighting system consists of only directional lamp types, such as PAR, R, MR, AR, or of luminaires providing directional display light.
   c. If track lighting is used, only track heads that are classified as directional lighting types.
3. To qualify for additional task lighting power:
   a. The task lighting system shall be located immediately adjacent to and capable of illuminating the task for which it is installed.
   b. The lighting system shall be of a type different from the general lighting system.
   c. The lighting system shall be separately switched from the general lighting system
4. To qualify for the additional power for floor display and task lighting, the lighting system shall be a type that is appropriate for creating a higher level of illuminance on the floor display or task.
5. The additional power for floor display and task lighting is not available for the following:
   a. Any function areas using the Complete Building or Area Category methods of compliance.
   b. Displays that are installed against a wall shall not qualify for the floor display lighting power allowances.
   c. Any floor area designed to not have floor displays or tasks, such as floor areas designated as a path of egress, shall not be included for the floor display allowance.

6. For floor areas qualifying for both floor display and task lighting power allowances, the additional allowed power shall be used only once for the same floor area so that the allowance shall not be additive.

D. Additional Decorative/Special Effects Lighting Power

Special effects lighting is defined as lighting installed to give off luminance instead of providing illuminance, which does not serve as general, task, or display lighting.

Qualifying decorative lighting includes luminaires such as chandeliers, sconces, lanterns, neon and cold cathode, light-emitting diodes, theatrical projectors, moving lights, and light color panels when any of those lights are used in a decorative manner that does not serve as display lighting or general lighting.

Additional allowed power for decorative/special effects lighting may be used only for the listed primary function areas in Table 140.6-D.

1. The additional allowed power for decorative/special effects lighting shall be the smaller of:
   a. The allowed decorative/special effects lighting power values (column 5 of Table 140.6-D) multiplied by the square footage of the floor areas having decorative/special effects lighting.
   b. The adjusted lighting power used for decorative/special effects lighting.
2. Additional decorative and special effects lighting power is not available for any function area using the Complete Building or Area Category methods of compliance.
3. Additional decorative/special effects lighting power shall be used only in areas having decorative/special effects lighting.

   Any floor area not designed to have decorative or special effects lighting shall not be included for the decorative/special effects lighting allowance.

E. Additional Very Valuable Display Case Lighting Power

Case lighting is defined as lighting of small art objects, artifacts, or valuable collections that involves customer inspection of very fine detail from outside a glass enclosed display case.

Additional allowed lighting power for very valuable display case lighting shall be available only for display cases in retail merchandise sales, museum, and religious worship areas.

1. The additional allowed power for very valuable display case lighting shall be the smallest of one of the following:
   a. The product of the area of the primary function and 0.50 watt per sq. ft.

   b. The product of the area of the display case and 7 watts per sq. ft.
   c. The adjusted lighting power used for very valuable display case lighting.

2. To qualify for additional allowed power for very valuable display case lighting, a case shall contain jewelry, coins, fine china, fine crystal, precious stones, silver, small art objects and artifacts, and/or valuable collections, the display of which involves customer inspection of very fine detail from outside a locked case.
3. The additional very valuable display case lighting is not available for any function areas using the complete building or area category methods of compliance.
4. Qualifying lighting includes internal display case lighting or external lighting employing highly directional luminaires specifically designed to illuminate the case or inspection area without spill light and shall not be fluorescent lighting unless installed inside of a display case.

Example 5-24: Decorative Lighting and Very Valuable Display Lighting — Tailored Method (Five Parts) (Part 1)

Question

A 5,500-ft² retail store has:

5,000 ft² of gross retail sales area (merchandise sales) with a RCR of 2.5
200 ft² of restrooms (with a RCR of 6.0)
300 ft² of corridors (with a RCR of 6.5)
100 ft² of very valuable merchandise case top with 1,200 W of light sources

As part of the retail scheme in the sales floor area, the following lighting is being used.

- Wall display lighting of 300 linear feet of perimeter wall including closeable openings
- Floor display lighting
- Decorative/special effects lighting.

What is the allowed lighting power for general lighting in this store using the Tailored Method?

Answer

The general illumination level is 500 Lux per Table 140.6-D for merchandise sales and showroom area in retail. Per Table 140.6-G, the lighting power density (LPD) is 0.90 W/ft² for a 500 Lux space with an RCR of 2.5. Therefore, the allowed general lighting power for the retail sales area is 0.90 W/ft² X 5,000 ft² = 4,500 W.

Corridors and restrooms are not included in the Tailored Method tables and therefore must comply under the area category method. Look up Table 140.6-C for the allowed LPD for these spaces. Table 140.6-C allows general lighting power LPD of 0.40 W/ft² for corridors and 0.65 W/ft^2 for restrooms. *(The RCR is not used for the area category method)*

The allowed power for the restrooms is 200 ft² x 0.65 W/ft² = 130 W.

The allowed power for the corridors is 300 ft² x 0.40 W/ft² = 120 W.

Note that for the Tailored Method, the allowed wattage for each lighting task other than general lighting is of the use-it-or-lose-it variety, which prohibits trade-offs among these wattages and different tasks or areas. Only the General Lighting component of the Tailored Method is tradable between areas using tailored method or areas using area category method.

Example 5-25: Wall Display Lighting – Tailored Method (Continue – Part 2)

Question

If the adjusted lighting power of the floor display luminaires is 3,000 watts, what is the allowed wall display lighting power for the retail sales area in this store?

Answer

The wall display lighting is computed from the entire wall perimeter, including all closeable openings, multiplied by the wall display power allowance. The allowed lighting power density value (for wall display lighting in merchandise sales and showroom areas of retail sales) is 11.5 W/ft as indicated in column 3 of Table 140.6-D. Therefore, the wall display lighting is 300 ft. x 11.5 W/ft. = 3,450 W..

Note that in the Tailored Method, the wall display lighting allowance is a use-it-or-lose-it allowance.

The additional allowed power for wall display lighting is the smaller of:

- The wall display lighting power allowance of 3,450 W, as calculated from above.
- The adjusted lighting power used for the wall display lighting, 3,000 W.

Since the smaller of 3,450 W and 3,000 W is 3,000 W, the additional allowed power for wall display lighting is 3,000 W for the retail sales area in this store.

Example 5-26: Floor Display Lighting – Tailored Method (Continue – Part 3)

Question

If the adjusted lighting power of the floor display luminaires is 4,000 watts, what is the allowed floor display lighting power for this store?

Answer

The floor display allowance is computed from the area of the entire space with floor displays multiplied by the floor display lighting power density. Therefore, the allowed wattage is 5,000 ft² x 0.7 W/ft² = 3,500 W. The allowance is taken from column 4 of Table 140.6-D.

Note that in the Tailored Method, the floor display power allowance is a use-it-or-lose-it allowance.

The additional allowed power for floor display lighting is the smaller of:

- The floor display lighting power allowance of 3,500 W, as calculated from above.
- The adjusted lighting power used for the floor display lighting, 4,000 W.

Since the smaller of 3,500 W and 4,000 W is 3,500 W, the additional allowed power for floor display lighting is 3,500 W for the retail sales area in this store.

Example 5-27: Decorative/Special Effect Lighting – Tailored Method (Continue – Part 4)

Question

If the adjusted lighting power of the decorative/special effect luminaires is 4,000 watts, what is the allowed decorative/special effect lighting power for this store?

Answer

The decorative/special effect allowance is computed from the area of the entire space with floor displays times the decorative/special effect lighting power density. Therefore, the allowed wattage is 5,000 ft² x 0.35 W/ft² = 1,750 W. The allowance is taken from column 5 of Table 140.6-D.

Note that in the Tailored Method, the decorative/special effect lighting allowance is a use-it-or-lose-it allowance.

The additional allowed power for decorative/special effect lighting is the smaller of:

- The decorative/special effect lighting power of 1,750 W, as calculated from above.
- The adjusted lighting power used for the decorative/special effect lighting, 4,000 W.

Since the smaller of 1,750 W and 4,000W is 1,750 W, the additional allowed power for decorative/special effect lighting is 1,750 W for the retail sales area in this store. The decorative/special effect lighting must be redesigned so that the adjusted wattage is reduced to no more than 1,750 W or the excess wattage must be taken from the general lighting power allowance provided there is extra wattage available.

Example 5-28: Very Valuable Display Case Lighting – Tailored Method (Continue – Part 5 of 5)

Question

If the adjusted lighting power of the very valuable display case lighting is 1,200 watts, what is the allowed very valuable display case lighting power for this store?

Answer

The allowed wattage for very valuable display case top is smaller of the product of 0.50 W/ft² and the gross sales area (5,000 ft²) or the product of 7 W/ft² and the actual area of the case tops (100 ft²) or the adjusted lighting power of the very valuable display case lighting.

The allowed lighting power is the smaller of one of the following:

- 0.50 W/ft² X 5,000 ft² = 2,500 watts
- 7 W/ft² X 100 ft² = 700 watts
- The adjusted lighting power of very valuable display case lighting, 1,200 watts.

Therefore, the additional allowed power for very valuable display case lighting is 700 W.

The very valuable display case lighting will need to be redesigned to reduce the adjusted wattage to no more than 700 W, or the excess wattage must be taken from the general lighting power allowance provided there is extra wattage available.

Example 5-29: Retail Space – Full Height Partitions

Question

A large retail store with a sales area that has a 14-foot high ceiling and full height perimeter wall also has several other walls and a high fixture element in the space. Based on the definition of "full-height" interior partitions (per §140.6[c]3Giii), which components qualify for the wall display lighting allocation?

Answer

The figure below shows full height interior partitions and partial height interior partitions.

Figure 5-23: (Example 5-29) Retail Lighting in Application — Partitions Qualifying for Wall Display Lighting Power Under Tailored Method

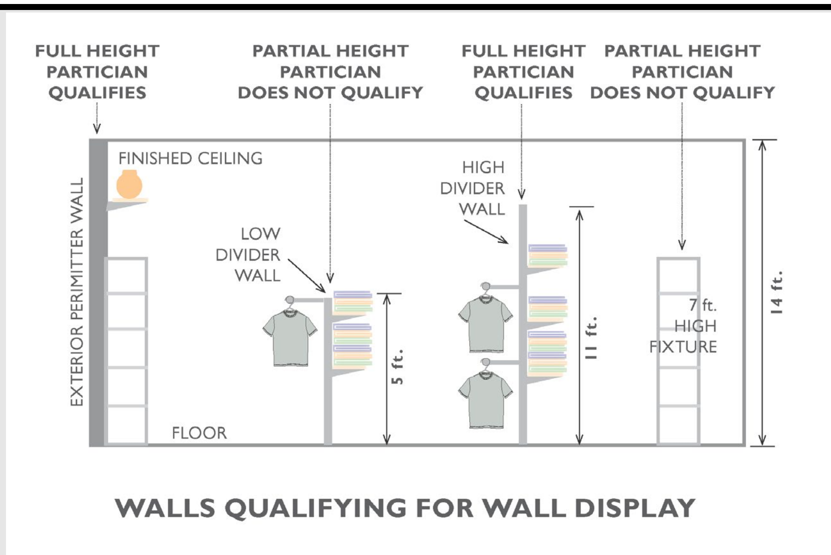


Image Source: California Energy Commission

Full height interior partitions extend from the floor to within two feet of the ceiling or are taller than 10 feet. Full height partitions must also be permanently anchored to the floor.

Example 5-30: Wall Display Lighting in a Retail Store – Tailored Method

Question

In the following figure, Condition A has 2 x 4 troffers placed 3 feet from a perimeter sales wall as well as fluorescent wall-washers 5 feet from the sales wall. Condition B has fluorescent wall-washers 3 feet from the wall and PAR adjustable accent lights 5 feet from the wall. Which luminaires qualify for the wall display lighting allocation?

Answers

Figure 5-24: (Example 5-30) Retail Lighting in Application — Walls Qualifying for Wall Display Lighting Power Under Tailored Method

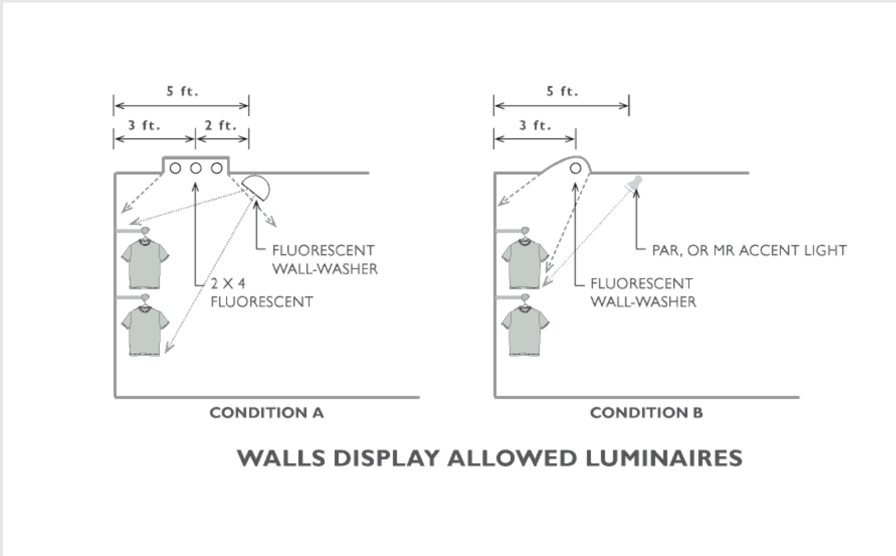


Image Source: California Energy Commission

Per §140.6(c)3Giia, qualifying lighting must be mounted within 10 feet of the wall and must be an appropriate wall lighting luminaires. (Luminaires with asymmetric distribution toward the wall or adjustable directed toward the wall).

CONDITION A

While both luminaires are within 10 feet of the wall only the wall-washer qualifies for the wall display allocation. The 2 x 4 troffer is a general lighting luminaire with symmetric distribution and does not qualify for the allocation.

CONDITION B

Both luminaires are within 10 feet of the wall, and both qualify for the wall display allocation. The fluorescent wall-washer has an asymmetric distribution and the PAR accent light at 5 feet from the wall provides directional light.

Example 5-31: Lighting Power Adjustments for Luminaire Mounting Height – Tailored Method

Figure 5-25: (Example 5-31) Lighting Power Adjustments for Luminaire Mounting Height

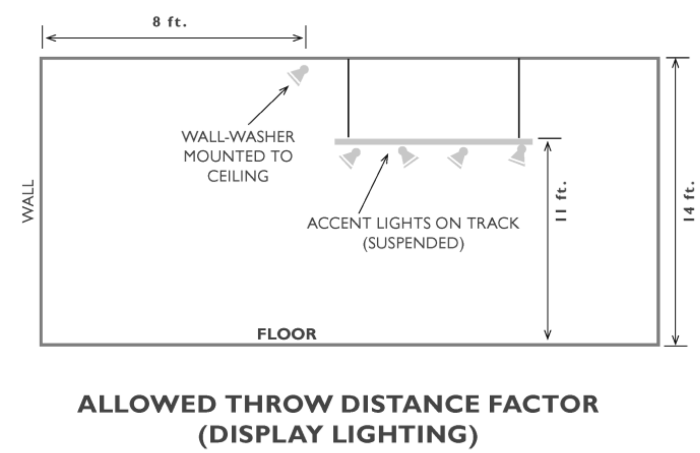


Image Source: California Energy Commission

Question

A high ceiling space with allowed display lighting has wall-washers mounted on the ceiling near the wall and accent lights mounted on suspended track in the center of the space. Because of the 14-foot high ceiling, does the display lighting qualify for a mounting height factor adjustment?

Answer

Per §140.6(c) 3Giv and 3Hviii, both the wall-washers and accent lights qualify for the mounting height adjustment as they are mounted at height greater than 10 feet 6 inches and they also provide directional light.

If the track is suspended at 10 feet instead of 11 feet, it is excluded from an adjustment factor and must use the default factor of one with the allowed LPD as shown in column four in Table 140.6-E.

5.8 Performance Compliance Approaches

The performance approach is an alternative to the prescriptive approach. The allowed lighting power is calculated as part of the energy budget for the proposed design building. A building complies with the performance approach if the energy budget calculated for the proposed design building is no greater than the energy budget calculated for the standard design building.

Under the performance approach, the energy use of the building is modeled using a compliance software program approved by the CEC. In this energy analysis, the standard lighting power density for the building is determined by the compliance software program based on occupancy type, in accordance with either the complete building, area category, or tailored method described above. This standard lighting power density is used to determine the energy budget for the building.

When a lighting permit is sought under the performance approach, the applicant uses a proposed lighting power density to determine whether or not the building meets the energy budget. If it does, this proposed lighting power density is automatically translated into the allowed lighting power for the building (by multiplying by the area of the building).

If the building envelope or mechanical systems are included in the performance analysis (because they are part of the current permit application), then the performance approach allows energy trade-offs between systems that can let the allowed lighting power go higher than any other method. Alternatively, it allows lighting power to be traded away to other systems, which would result in a lower allowed lighting power. This flexibility in establishing allowed lighting power is one of the more attractive benefits of the performance approach.

General lighting power is the power used by installed electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect, exclusive of daylighting, and also known as ambient lighting.

Trade-offs in general lighting power are allowed between all spaces using the Area Category Method, between all spaces using the Tailored Method, and between all spaces using the Area Category and Tailored Methods.

Also, with the Area Category Method and the Tailored Method, the Energy Code provides an additional lighting power allowance for special cases. Each of these lighting system cases is treated separately as "use-it-or-lose-it" lighting. The user receives no credit (standard design matches proposed), but there is a maximum power allowance for each item.

See the 2022 Nonresidential ACM Reference Manual for additional information.

5.9 Lighting Control Installation and Acceptance Requirements – for Installers and Acceptance Test Technicians

With the onset of the construction phase of projects, two types of documentation must be prepared for showing compliance to the Energy Code — certificate of installation and certificate of acceptance.

The following sections layout the scope of these types of certification and the related parts of the Nonresidential Appendix that contain the acceptance testing procedures. Refer to Section 5.11 for a list of certificate of installation and certificate of acceptance documents.

5.9.1 Lighting Installation Certificate Requirements (§130.4[b])

The person eligible under Division 3 of the Business and Professions Code to accept responsibility for the installation or construction of features, materials, components, or manufactured devices shall sign and submit the certificate of installation for installation of the following items before any of the following applications will be recognized for compliance with the lighting requirements:

1. Lighting Control System
2. Energy Management Control System
3. Interlocked lighting systems serving a single space.
4. Lighting controls installed to earn a lighting power adjustment factor (PAF)
5. Additional lighting wattage available for a videoconference studio

If any of the requirements in the certificate of installation are not met, that application shall not be recognized for compliance with the Energy Code.

See Section 5.11.6 for more information on certificate of installation documents.

5.9.2 Lighting Control Acceptance Requirements (§130.4[a])

Acceptance testing must be performed by a certified lighting controls acceptance test technician to certify the indoor and outdoor lighting controls serving the building, area, or site will meet the acceptance requirements.

A certificate of acceptance shall be submitted to the local enforcement agency under §10-103(a) of Part 1 and §130.4(a), that:

1. Certifies that all of the lighting acceptance testing necessary to meet the requirements of Part 6 is completed.
2. Certifies that the applicable procedures in Reference Nonresidential Appendix NA7.6 and NA7.8 have been followed.
3. Certifies that automatic daylight controls comply with §130.1(d) and Reference Nonresidential Appendix NA7.6.1.
4. Certifies that lighting shut off controls comply with §130.1(c) and Reference Nonresidential Appendix NA7.6.2.
5. Certifies that demand-responsive controls comply with §130.1(e) and Reference Nonresidential Appendix NA7.6.3.
6. Certifies that outdoor lighting controls comply with the applicable requirements of §130.2(c) and Reference Nonresidential Appendix NA7.8.

7. Certifies that lighting systems receiving the institutional tuning power adjustment factor comply with §140.6(a)2J and Reference Nonresidential Appendix NA7.6.4.

5.10 Additions and Alterations

5.10.1 Overview

New additions, similar to newly constructed buildings, must meet all mandatory measures for the prescriptive and performance method of compliance. Prescriptive requirements, including the lighting power densities, must be met if the prescriptive method of compliance is used. If the performance approach is used and the new addition includes envelope or mechanical systems in the performance analysis, the lighting power densities may be traded-off against other system energy budgets.

Alterations to indoor lighting systems that include 10 percent or more of the existing luminaires serving an enclosed space must meet the indoor lighting alteration requirements in §141.0(b)2I. Indoor lighting alterations include adding luminaires, removing and reinstalling luminaires, modifying luminaires, or combining the replacement of lamps and ballasts or drivers. Alterations to wiring serving lighting are also lighting alterations.

Any space with a lighting system installed for the first time must meet the same lighting requirements as a newly constructed building.

5.10.2 Additions

§141.0(a)

The nonresidential indoor lighting of the addition shall meet either the prescriptive approach or the performance approach.

When using the prescriptive approach, the indoor lighting in the addition must meet the lighting requirements of §110.0, §110.9, §130.0 through §130.5, §140.3, and §140.6.

When using the performance approach, the indoor lighting in the addition must meet the lighting requirements of §110.0, §110.9, §130.0 through §130.5, and one of the following two options of the performance requirements:

1. The addition alone meet §140.1
2. The existing building plus the addition plus the alteration.

5.10.3 Alterations – General Information

§141.0(b)

5.10.3.1 Scope

Alterations to existing nonresidential, hotel/motel, or relocatable public-school buildings or alterations in conjunction with a change in building occupancy to a nonresidential, or hotel/motel occupancy shall meet one of the following requirements:

i. Comply with the requirements for additions.

ii. Comply with the prescriptive lighting requirements.

iii. Comply with the performance approach.

An alteration as defined by the Energy Code includes:

i. Any change to a building water-heating system, space-conditioning system, lighting system, electrical power distribution system, or envelope that is not an addition.

ii. Any regulated change to an outdoor lighting system that is not an addition

iii. Any regulated change to signs located either indoors or outdoors.

iv. Any regulated change to a covered process that is not an addition.

An altered component is defined by the Energy Code as a component that has undergone an alteration and is subject to all applicable requirements.

5.10.3.2 Indoor Lighting Alteration Exceptions

The following indoor lighting alterations are not required to comply with the lighting requirements in the Energy Code:

1. Alterations where less than 10 percent of existing luminaires in an enclosed space are being altered.
2. Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by §140.6(a)3.
3. In an enclosed space where there is only one luminaire.
4. Any alteration that would directly cause the disturbance of asbestos unless the alterations are made in conjunction with asbestos abatement.
5. Alterations limited to addition of lighting controls or replacing lamps, ballasts, or drivers.
6. One-for-one luminaire alteration of up to 50 luminaires either per complete floor of the building or per complete tenant space, per annum.

5.10.3.3 Skylight Exception

When the daylighting control requirements of §130.1(d) are triggered by the addition of skylights to an existing building and the lighting system is not re-circuited, the daylighting control need not meet the multilevel requirements in §130.1(d). Daylit areas must be controlled separately from nondaylit areas. An automatic control must be able to reduce lighting power by at least 90 percent when the daylit area is fully illuminated by daylight.

5.10.3.4 Alterations – Performance Approach

When using the Performance Approach (using a software program certified to the Energy Commission) the altered envelope, space conditioning system, lighting and water heating components, and any newly installed equipment serving the alteration shall meet the applicable requirements of §110.0 through §110.9, §120.0 through §120.6, and §120.9 through §130.5.

5.10.3.5 Alterations – Prescriptive Approach

When using the Prescriptive Approach, the altered lighting shall meet the applicable requirements of §110.0, §110.9, and §130.0 through §130.4.

5.10.4 Indoor Lighting Alterations

§141.0(b)2I

Alterations to the lighting systems must comply with the requirements in §141.0(b)2I when 10 percent or more of the luminaires serving an enclosed space are altered.

The Energy Code compliance goals for the lighting alterations are twofold. First, the installation must meet the lighting power requirements; second, the installation must provide lighting controls.

The Energy Code allows three options for meeting the installed power and associated control requirements and specifies a set of requirements for lighting power allowance and controls for each of the following cases:

1. The altered lighting power does not exceed the indoor lighting power requirements specified in §140.6,
2. The altered lighting power is equal to or less than 80 percent of indoor lighting power requirements specified in §140.6, or
3. The alteration is a one-for-one luminaire alteration within a building or tenant space of 5,000 sq. ft. or less, and the total wattage of the altered luminaires is at least 40 percent lower compared to the total prealteration wattage.

Altered lighting systems must meet one of the three requirements above for lighting power allowance. Options 1 and 2 require the lighting power allowance to be calculated according to §140.6.

Option 3 allows the maximum installed lighting power to be determined by taking a percentage of the existing installed lighting power, rather than measuring the square footage of the space and multiplying it by a lighting power allowance. Option 3 is allowed only for one-for-one luminaire alterations. One-for-one is defined as either replacement of whole luminaires one for one, in which the only electrical modification involves disconnecting the existing luminaire and reconnecting the replacement luminaire, or when components of a luminaire are modified without replacing the entire luminaire.

5.10.4.1 Indoor Lighting Alteration Control Requirements

The control requirements for each option are described in Table 5-3.

Option 1 requires indoor lighting alterations to meet all the mandatory control requirements that are applicable to the project. The control requirements include manual area controls, multilevel controls, automatic shutoff controls, daylighting controls, and demand-responsive controls.

Options 2 and 3 are likely to result in a lower lighting power than Option 1; therefore, indoor lighting alterations must meet manual area control and automatic shut off control requirements. In offices larger than 250 square feet, occupant sensing shutoff controls are not required for Options 2 and 3. Multilevel lighting controls (§130.1[b]), daylighting controls (§130.1[d]), and demand-responsive controls (§130.1[e]) are not required for Options 2 and 3.

Alterations to indoor lighting systems shall not prevent the operation of existing, unaltered controls and shall not alter controls to remove functions specified in §130.1. Alterations to indoor lighting systems are not required to separate existing general, floor, wall, display, or decorative lighting on shared circuits or controls. New or completely replaced lighting circuits shall comply with the control separation requirements of §130.1(a)4 and 130.1(c)1D.

The acceptance testing requirement of §130.4 is not required for alterations where lighting controls are added to control 20 or fewer luminaires for the entire alteration project.

Table 5-3 (Modified from Table 141.0-F): Control Requirement for Indoor Lighting Alteration

Control Specifications	Control Specifications	Projects complying with §141.0(b)2Ii (Option 1)	Projects complying with §141.0(b)2Iii and §141.0(b)2Iiii (Option 2 and 3)
Manual Area Controls	130.1(a)1	Required	Required
Manual Area Controls	130.1(a)2	Required	Required
Manual Area Controls	130.1(a)3	Only required for new or completely replaced circuits	Only required for new or completely replaced circuits
Multilevel Controls	130.1(b)	Required	Not Required
Automatic Shut Off Controls	130.1(c)1	Required; 130.1(c)1 D only required for new or completely replaced circuits	Required; 130.1(c)1D only required for new or completely replaced circuits
Automatic Shut Off Controls	130.1(c)2	Required	Required
Automatic Shut Off Controls	130.1(c)3	Required	Required

Control Specifications	**Control Specifications**	**Projects complying with §141.0(b)2Ii (Option 1)**	**Projects complying with §141.0(b)2Iii and §141.0(b)2Iiii (Option 2 and 3)**
Automatic Shut Off Controls	130.1(c)4	Required	Required
Automatic Shut Off Controls	130.1(c)5	Required	Required
Automatic Shut Off Controls	130.1(c)6	Required	Required; except for 130.1(c)6D
Automatic Shut Off Controls	130.1(c)7	Required	Required
Automatic Shut Off Controls	130.1(c)8	Required	Required
Daylighting Controls	130.1(d)	Required	Not Required
Demand-Responsive Controls	130.1(e)	Required	Not Required

Example 5-32: Warehouse Luminaire Alteration With 40 Percent Lighting Power Reduction

Question

All existing luminaires in a warehouse facility of 5,000 sq. ft. are proposed to be replaced by LED luminaires (shown below). There are 100 existing metal halide luminaires, and each uses 250 watts, all of which will be replaced. The replacement LED luminaires use 150 watts each. How is compliance being determined, and what controls are required?

Answer

The compliance option of §141.0(b)2Iiii requires a 40 percent reduction in installed lighting power for one-to-one luminaire alterations within a building or tenant space of 5,000 square feet or less. Thus, enter the number and wattage of the existing luminaires into NRCC-LTI, and use the form to calculate both the existing installed lighting power (100 x 250 W = 25,000 W) and the maximum allowance based on a 40 percent reduction (25,000 W x 0.6 = 15,000 W). Enter the number and wattage of the new luminaires into NRCC-LTI, just like any other project. This is a one-for-one replacement, so the total lighting power of the new luminaires meets the allowance (100 x 150 W = 15,000 W).

Since the alteration meets §141.0(b)2Iiii, only manual area controls and automatic shut off controls are mandatory as specified in Table 141.0-F (Table 5-2 in this manual).

Example 5-33: Lighting Wiring Alterations

Question

If the lighting system is being rewired as part of a lighting alteration project, which Energy Code requirements must be complied with?

Answer

Alterations to lighting wiring are considered alterations to the lighting system, so the requirements are the same as for lighting system alterations. Only altered components of the alteration must meet applicable requirements. For example, rewiring or relocating existing controls will trigger applicable requirements for the existing controls. If existing luminaires are not altered, they would not be held to alteration requirements such as lighting power allowance requirements or additional control requirements in §141.0(b)2I.

Altered lighting circuits must comply with the control requirements as specified in §130.1(a)3.

The acceptance testing requirements are triggered if controls are added to control more than 20 luminaires.

Example 5-34: Alterations Projects Replacing Both Lamps and Ballasts of the Luminaires

Question

There are 100 lighting fixtures in an existing office space. For 20 fixtures, the internal components (lamps and ballasts) are being replaced with retrofit kits.

Which Energy Code requirements apply?

Answer

Because 20 out of 100 (or 20 percent) of the luminaires are altered, which is more than the 10 percent of existing luminaires in the space, the alteration must meet either §141.0(b)2Ii or §141.0(b)2Iii. Moreover, removing and replacing both lamps and ballasts with retrofit kits are considered one-for-one luminaire alteration. Therefore, the alteration could meet §141.0(b)2Iiii instead of §141.0(b)2Ii or §141.0(b)2Iii if the total wattage of the altered luminaires has been reduced by at least 40 percent and if the altered building or tenant space is 5,000 square feet or less.

Example 5-35: One-for-One Alterations in Enclosed Spaces With One Luminaire

Question

A project includes more than 50 luminaires with one-for-one alterations on a floor, but a portion of those altered luminaires are in enclosed spaces containing one luminaire.

How are the luminaires in the enclosed spaces counted toward the trigger threshold of 50 luminaires under §141.0(b)2I in a one-for-one luminaire alteration?

Answer

Although Exception 2 to §141.0(b)2I exempts enclosed spaces with one luminaire from the requirements of §141.0(b)2I, it does not reduce the total luminaire count on a floor or a tenant space. Therefore, the altered luminaires on the floor that are not in the spaces with one luminaire are required to meet the requirements of either §141.0(b)2Ii, §141.0(b)2Iii, or §141.0(b)2Iiii.

Example 5-36: Lamp Replacements as Part of a Project

Question

A single-story retail store has 50 T12 linear fluorescent strip luminaires and two sections of track lighting. One of the tracks has 10 screw-in incandescent flood lights and the other track has 10 pin-based halogen PAR lamps. The linear luminaires are being retrofitted with T8 lamps and premium ballasts. In the track luminaires, the screw-in and pin-based incandescent lamps are being replaced with equivalent screw-in and pin-based LED lamps. There are no other alterations done to the lighting system of that tenant space in the calendar year.

What are the Energy Code requirements for this project?

Answer

There are a total of 70 luminaires (50+10+10 = 70 luminaires).

Out of the 70 fixtures included in the project, the 20 incandescent fixtures consist of lamp replacement only and do not count toward the trigger threshold of more than 50 luminaires under §141.0(b)2I (one-for-one luminaire alteration). Only 50 luminaires are being altered in this job. The Energy Code is not triggered for this project because 50 or fewer fixtures are being modified.

Example 5-37: Energy Code for Lighting Wiring Alterations

Question

If occupancy sensing controls are added to a suite of office spaces, does this addition trigger the requirements of §141.0(b)2I (Indoor Lighting Alterations)?

Answer

No, since the alterations are limited to the addition of occupancy sensing controls, it does not trigger any of the requirements of §141.0(b)2I.

Example 5-38: Daylighting Requirements for Large Enclosed Spaces

Question

A 30,000 ft^2 addition has a 16,000 ft^2 space with an 18-ft. high ceiling and a separate 14,000 ft^2 space with a 13 ft high ceiling. The lighting power density in this building is 1 W/ft^2. Do skylights have to be installed in the portion of the building with 18-foot ceiling?

Answer

Yes. Section 140.3(c) requires daylighting in enclosed spaces that are greater than 5,000 ft^2 directly under a roof with a ceiling height over 15 feet. In this example the area with a ceiling height greater than 15 feet is 16,000 ft^2; therefore, prescriptive daylighting requirements apply. (Note: Daylighting requirements do not apply in Climate Zones 1 and 16).

Example 5-39: Daylighting Requirements for Alterations

Question

A preexisting air-conditioned 30,000 ft^2 warehouse with a 30 ft. ceiling and no skylights will have its general lighting system replaced as part of a conversion to a big box retail store. Are skylights prescriptively required?

Answer

No. The general lighting system is being replaced and is not "installed for the first time." Thus, §141.0(b)2F does not apply and therefore does not trigger the requirements in §140.3(c) for daylighting.

5.11 Indoor Lighting Compliance Documents

5.11.1 Overview

This subchapter describes the documentation (compliance forms) required for compliance with the nonresidential indoor lighting requirements of the Energy Code.

5.11.2 Submitting Compliance Documentation

At the time a building permit application is submitted to the local enforcement agency, the applicant also submits building plans and energy compliance documentation. This section describes the recommended compliance documentation (forms) for complying with the nonresidential indoor lighting Energy Code. It does not describe the details of the requirements.

This section is addressed to the person preparing building plans and compliance documents and to the local enforcement agency plan checkers who are examining those documents for compliance.

5.11.3 Separately Documenting Conditioned and Unconditioned Spaces

The nonresidential indoor lighting requirements are the same for conditioned and unconditioned spaces. However, the Energy Code does not allow lighting power trade-offs to occur between conditioned and unconditioned spaces. Therefore, most nonresidential indoor lighting compliance forms are required to be separately completed for conditioned and unconditioned spaces.

5.11.4 Compliance Documentation Numbering

Following is an explanation of the nonresidential lighting compliance documentation numbering:

- NRCC Nonresidential Certificate of Compliance.
- NRCA Nonresidential Certificate of Acceptance.
- NRCI Nonresidential Certificate of Installation.
- LTI Lighting, Indoor.
- LTO Lighting, Outdoor.
- LTS Lighting, Sign.
- E Primarily used by enforcement authority.
- A Primarily used by acceptance tester.

5.11.5 Certificate of Compliance Documents

There is only one nonresidential indoor lighting certificate of compliance document (form) required to be filled out for each project.

- NRCC-LTI-E; Certificate of Compliance; Indoor Lighting.

The certificate of compliance must be submitted for all buildings that demonstrate compliance with the nonresidential indoor lighting requirements. The certificate of compliance documents installed lighting power, lighting power allowance calculations, mandatory controls, PAFs, and other lighting requirements in the Energy Code.

5.11.6 Certificates of Installation Documents

There are six certificates of installation listed as follows. See Section 5.9.1 of this chapter for additional information.

- NRCI-LTI-01-E, Certificate of Installation, Indoor Lighting
- NRCI-LTI-02-E, Certificate of Installation, Lighting Control Systems
- NRCI-LTI-04-E, Certificate of Installation, Two Interlocked Lighting Systems
- NRCI-LTI-05-E, Certificate of Installation, Power Adjustment Factors
- NRCI-LTI-06-E, Certificate of Installation, Additional Video Conference Studio Lighting

The certificate of installation is used primarily as a declaration that the installed lighting and controls matches what is claimed on the certificate of compliance. The certificate of installation is signed by the licensed person that completed the installation.

The required nonresidential indoor lighting certificates of installation include the following:

- NRCI-LTI-01-E — must be submitted for all buildings. This is the general certificate of installation used to declare that what was proposed in the certificates of compliance is what was installed.

In addition to the NRCI-LTI-01-E, the following certificates of installation are also required if the job includes any of the measures covered by these certificates of installation. If any of the requirements in any of these certificates of installation fail the respective installation requirements, then that application shall not be recognized for compliance with the lighting standards.

- NRCI-LTI-02-E — Must be submitted whenever a lighting control system, and whenever an energy management control system (EMCS), have been installed to comply with any of the lighting control requirements.
- NRCI-LTI-04-E — Must be submitted for two interlocked systems serving an auditorium, a convention center, a conference room, a multipurpose room, or a theater to be recognized for compliance.

  See Section 5.6.2 of this chapter for two interlocked system requirements.
- NRCI-LTI-05-E — Must be submitted for a power adjustment factor (PAF) to be recognized for compliance.

  See Section 5.6.2 of this chapter for requirements of PAFs.

- NRCI-LTI-06-E — Must be submitted for additional wattage installed in a video conferencing studio to be recognized for compliance

5.11.7 Certificate of Acceptance

Acceptance requirements ensure that equipment, controls, and systems operate as required by the Energy Code. Acceptance testing consists of:

- Visual inspection of the equipment and installation.
- Functional testing of the systems and controls.

Individual acceptance tests may be performed by one or more field technicians under the responsible charge of a licensed contractor or design professional, (responsible person) eligible under Division 3 of the Business and Professions Code, in the applicable classification, to accept responsibility for the scope of work specified by the certificate of acceptance document. The responsible person must review the information on the certificate of acceptance form and sign the form to certify compliance with the acceptance requirements:

Typically, the individuals who perform the field testing/verification work and provide the information required for completion of the acceptance form (field technicians) are contractors, engineers, or commissioning agents. Field technicians do not need to be a third-party and are not required to be licensed contractors or licensed design professionals. Only the responsible person who signs the certificate of acceptance form certifying compliance must be licensed.

When certification is required by Title 24, Part 1, §10-103.1, acceptance testing must be performed by a certified lighting controls acceptance test technician. Acceptance test technicians receive hands-on and classroom training on the testing procedures and must pass an exam to become certified. Acceptance test technicians are trained and certified by an Energy Commission approved Acceptance Test Technician Certification Provider.

The acceptance tests required for nonresidential indoor lighting include:

- Shutoff controls.
- Automatic daylighting controls.
- Demand-responsive lighting controls and demand-responsive controlled receptacles.
- Institutional tuning controls that qualify for a power adjustment factor.

Instructions for completing the certificates of acceptance are imbedded in the certificates. The lighting controls acceptance testing procedures are included in Nonresidential Reference Appendix NA7.6.

See Chapter 14 of this manual for additional information about acceptance requirements.

5.12 For Manufacturers and Installers

Lighting controls are no longer required to comply with Title 20 Appliance Efficiency Regulations effective March 16, 2021. Amendments to Title 20 removed the requirements for self-contained lighting controls therefore lighting controls are no longer required to comply with Title 20 to be sold or offered for sale in California or to be certified and listed in the web page, which is under the heading "Modernized Appliance Efficiency Database System (MAEDBS)."

5.12.1 Luminaire Labeling

130.0(c)1

Luminaires shall be labeled with its wattage as follows.

1. The maximum rated wattage or relamping rated wattage of a luminaire shall be listed on a permanent, preprinted, factory-installed label, as specified by UL 1574, 1598, 2108, or 8750, as applicable; and
2. Peel-off and peel-down labels that allow the maximum labeled wattage to be changed are prohibited, except for luminaires meeting the following requirements:
    a. The luminaires can accommodate a range of lamp wattages without changing the luminaire housing, ballast, transformer, or wiring.
    b. They have a single lamp.
    c. They have an integrated ballast or transformer.
    d. Peel-down labels are layered such that the rated wattage reduces as successive layers are removed.
    e. Qualifies as one of the following three types of luminaires:
        i. High-intensity discharge luminaires having an integral electronic ballast with a maximum relamping rated wattage of 150 watts.
        ii. Low-voltage luminaires (does not apply to low-voltage track systems) ≤ 24 volts with a maximum relamping rated wattage of 50 watts.
        iii. Compact fluorescent luminaires having an integral electronic ballast with a maximum relamping rated wattage of 42 watts.

Informational notes about UL 1598, 1574, 2108 and 8750:

The UL 1598 (Standard for Safety for Luminaires) applies to luminaires for use in nonhazardous locations and that are intended for installation on branch circuits of 600 V nominal or less between conductors in accordance with National Electrical Code. It does not apply to luminaires covered by other standards.

The UL 1574 (Standard for Safety for Track Lighting Systems) applies to track lighting systems intended for permanent connection to sources of supply in commercial or residential ordinary locations in accordance with the National Electrical Code.

The UL 2108 (Standard for Safety for Low Voltage Lighting Systems) applies to low voltage lighting systems and components intended for permanent installation and for use in locations in accordance with the National Electrical Code.

The UL 8750 (Standard for Safety for Light-Emitting Diode (LED) Equipment for Use in Lighting Products) applies to LED equipment that is an integral part of a luminaire or other lighting equipment. These requirements cover components including LED drivers, controllers, arrays (modules), and packages as defined within this standard.

Table of Contents

6. Outdoor Lighting

This chapter covers the Title 24 California Code of Regulations, Part 6 (Energy Code) requirements for nonresidential outdoor lighting systems design, installation, luminaires, and lighting controls.

This chapter is addressed primarily to lighting designers, electrical engineers, electrical contractors, energy consultants, manufacturers, local enforcement agency staff, others working on behalf of local government building departments, and still others who provide outreach and education of the Energy Code.

Chapter 5 addresses nonresidential indoor lighting requirements and covers lighting in parking garages.

Chapter 7 addresses sign lighting requirements.

Overview

What's New for the 2022 California Energy Code

The significant changes for outdoor lighting systems in the 2022 update to the Energy Code include:

- Lighting Zones 1-4 have new definitions according to U.S. Census designations for rural, urban cluster, and urban areas.
- Updates to lighting power allowances for general hardscape lighting in Table 140.7-A including reduction in lighting power allowances and using a single allowance for all hardscape surfaces instead of separate allowances for concrete and asphalt surfaces. Allowances follow IES RP-8 recommended practices.
- Updates to specific applications in Table 140.7-B, including addition of security camera application.
- All instances of the term "cutoff" have been updated to the term "shielding"; these terms refer to the same luminaire distribution features.
- See Section 11.6 for changes to the Multifamily Outdoor Lighting Compliance Manual.
- Reorganization of and improvement in phrasing of the outdoor lighting control requirements in §130.2(c) to enhance readability.

Scope, Approach, and Applications

This chapter applies to all nonresidential outdoor lighting, whether attached to buildings, poles, structures or self-supporting, including, but not limited to, lighting for hardscape areas such as parking lots, lighting for building entrances, lighting for all outdoor sales areas, and lighting for building façades.

The nonresidential outdoor lighting part of the Energy Code includes minimum control requirements, maximum allowable lighting power, and shielding (uplight and glare) zonal lumen limits for outdoor luminaires.

All section (§) and table references in this chapter refer to sections and tables contained in the Energy Code.

Refer to Residential Compliance Manual Chapter 6 for information on lighting requirements for single-family residential buildings.

Refer to Nonresidential Compliance Manual Chapter 14 for information on lighting requirements for multifamily buildings.

6.2.1 Outdoor Lighting Power Compliance Approach

Outdoor lighting power densities are structured using a layered lighting approach. With the layered approach, the first layer of allowed lighting power is general hardscape for the entire site. After the allowed lighting power has been determined for this first layer, additional layers of lighting power are allowed for specific applications when they occur on the site. For example, the total allowed power for a sales lot with frontage is determined by layering the general hardscape, outdoor sales lot, and outdoor sales lot frontage allowances, with specific restrictions associated with the location of the power used for frontage and sales lot lighting.

Figure 6-1: Concept of a Layered Lighting Approach for Outdoor Lighting — Lighting Power Allowance (LPA)

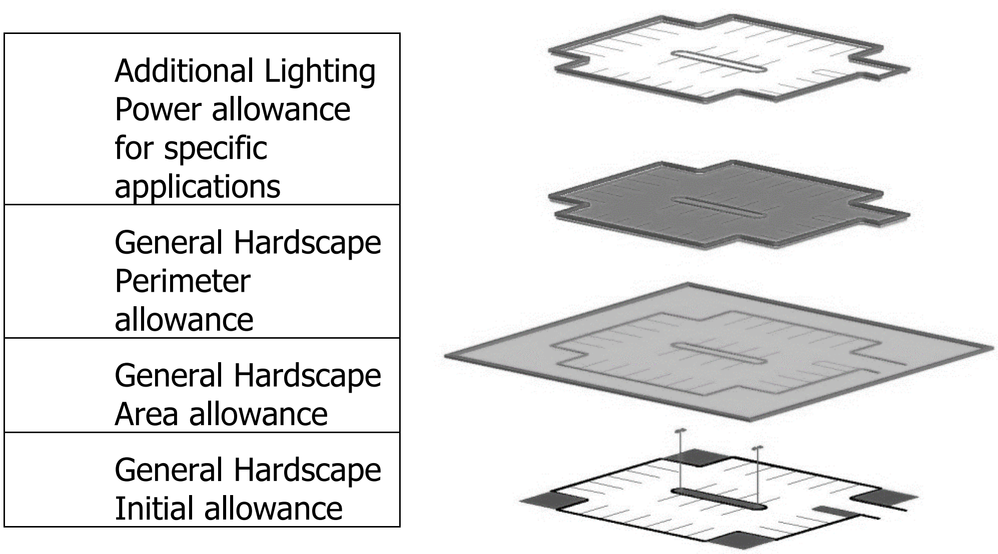


Image Source: California Energy Commission

The outdoor lighting applications that are addressed by the Energy Code are shown in the first two columns of Table 6-1. The first column is general site illumination applications, which allow trade-offs within the outdoor portion only. The second column is specific outdoor lighting applications, which do not allow trade-offs and are considered "use it or lose it." The lighting applications in the third column are exempt from lighting power requirements. However, these lighting applications must meet applicable lighting control requirements.

6.2.2 Lighting Power Trade-Offs

The Energy Code does not allow trade-offs between outdoor lighting power allowances and indoor lighting, sign lighting, heating, ventilation, and air-conditioning (HVAC) system, building envelope, or water heating (§140.7[a]).

There is only one type of trade-off permitted for outdoor lighting power. Allowed lighting power determined according to §140.7(d)1 for general hardscape lighting may be traded to specific applications in §140.7(d)2, provided the luminaires used to determine the illuminated area are installed as designed. This means that if luminaires used to determine the total illuminated area are removed from the design, resulting in a smaller illuminated area, then the general hardscape lighting power allowance must also be reduced accordingly.

Allowed lighting power for specific applications may not be traded between specific applications or to hardscape lighting in §140.7(d)1. This means that for each specific application, the allowed lighting power is the smaller of the allowed power determined for that specific application according to §140.7(d)2, or the actual installed lighting power that is used in that specific application. These additional power allowances are "use it or lose it" allowances.

Table 6-1: Scope of the Outdoor Lighting Requirements

Lighting Applications Covered General Hardscape (trade-offs permitted)	**Lighting Applications Covered Specific Applications (trade-offs not permitted)**	**Lighting Applications Not Regulated (only as detailed in §140.7)**
The general hardscape area of a site shall include parking lot(s), roadway(s), driveway(s), sidewalk(s), walkway(s), bikeway(s), plaza(s), bridge(s), tunnel(s), and other improved area(s) that are illuminated.	Canopies: Sales and Non-sales Tunnels Drive-Up Windows Emergency Vehicle Facilities Building Entrances or Exits Building Facades Guard Stations Hardscape Ornamental Lighting Outdoor Dining Primary Entrances for Senior Care Facilities, Police Stations, Healthcare Facilities, Fire Stations, and Emergency Vehicle Facilities Outdoor Sales Frontage and Lots Special Security Lighting for Retail Parking and Pedestrian Hardscape Student Pick-up/Drop-off zone Vehicle Service Station: Canopies, Hardscape, and Uncovered Fuel Dispenser ATM Lighting Security Cameras	Temporary outdoor lighting Required and regulated by FAA Required and regulated by the Coast Guard. For public streets, roadways, highways, and traffic signage lighting, and occurring in the public right-of-way For sports and athletic fields, and children's playground For industrial sites For public monuments Signs regulated by §130.3 and §140.8 For stairs and wheelchair elevator lifts For ramps that are not parking garage ramps Landscape lighting For themes and special effects in theme parks For outdoor theatrical and other outdoor live performances For qualified historic buildings

Source: California Energy Commission

Other outdoor lighting applications that are not included in Energy Code Tables 140.7-A or 140.7-B are assumed to be not regulated by the Energy Code. This includes decorative gas lighting and emergency lighting powered by an emergency source as defined by the California Electrical Code. The text in the above list of lighting applications that are not regulated has been shortened for brevity. Please see Section 6.2.3 for details about unregulated lighting applications.

6.2.3 Outdoor Lighting Applications Not Regulated by §140.7

When a luminaire is installed only to illuminate one or more of the following applications, the lighting power for that luminaire shall be exempt from the lighting power requirements in §140.7(a). Refer to the right column of Table 6-1 for a quick reference to the lighting applications that are exempted. Also, the Energy Code clarifies that at least 50 percent of the light from the luminaire must fall within an application to qualify as being installed for that application.

Outdoor Lighting Zones

The basic premise of the Energy Code is to base allowable outdoor lighting power on the brightness of the surrounding conditions. The Energy Code contains lighting power allowances for new lighting installations and specific alterations that depend on the lighting zone (LZ) in which the project is located.

Five categories of outdoor lighting zones are defined: LZ0, LZ1, LZ2, LZ3, and LZ4. Lighting zones with lower numbers are darker from LZ0, which is in national parks and other areas intended to be very dark at night, to LZ4 for high-intensity nighttime use, such as entertainment or commercial districts or areas with special security considerations requiring very high light levels. The eyes adapt to darker surrounding conditions, and less light is required to properly see. When the surrounding conditions get brighter, more light is needed to see. Providing greater power than is needed potentially leads to debilitating glare and an increasing spiral of brightness as overbright projects populate surrounding conditions causing future projects to unnecessarily require greater power resulting in wasted energy. The least power is allowed in LZ1, and increasingly more power is allowed in LZ2, LZ3, and LZ4. LZ0 is intended for undeveloped spaces in parks and wildlife preserves and is very low ambient illumination.

The following summarizes the default locations for outdoor lighting zones as specified in §10-114:

- Lighting Zone 0 includes undeveloped areas of government-designated parks, recreation areas, and wildlife preserves.
- Lighting Zone 1 includes developed portions of government designated parks, recreation areas, and wildlife preserves. LZ 1 also includes rural areas as defined by the 2010 United States (U.S.) Census.
- Lighting Zone 2 includes urban clusters as defined by the 2010 U.S. Census.
- Lighting Zone 3 includes urban areas as defined by the 2010 U.S. Census.
- Lighting Zone 4 includes special use districts that may be created by a local government through application to the California Energy Commission (CEC).

Lighting Zones 1-4 are designated according to 2010 U.S. Census definitions for rural areas, urban clusters, and urban areas. See below for details on rural areas, urban clusters, and urban areas and how they are related to lighting zones.

6.3.1 Parks, Recreation Areas, and Wildlife Preserves

The default lighting zone for undeveloped portions of government designated parks, recreation areas, and wildlife preserves is Lighting Zone 0.

The default lighting zone for developed portions of government designated parks, recreation areas, and wildlife preserves is Lighting Zone 1.

The local jurisdiction having authority over the property will know if the property is a government-designated park, recreation area, or wildlife preserve. However, a Lighting Zone 2 designation can be adopted if the property is surrounded by a default Lighting Zone 2 area (as defined by the U.S. Census Bureau). Similarly, when a park, recreation area, wildlife preserve, or portions thereof are surrounded by urban areas (as defined by the U.S. Census Bureau), such areas may be designated as Lighting Zone 3 by adoption of the local jurisdiction. All adjustments in lighting zone designation must be reviewed by the CEC for approval.

6.3.2 Rural Areas

The default for rural areas as defined by the U.S. Census Bureau is Lighting Zone 1. However, local jurisdictions may designate certain areas as Lighting Zone 2 if it is determined that ambient lighting levels are higher than typical for a rural area. Examples of areas that might be designated Lighting Zone 2 are retail stores located in residential neighborhoods or rural town centers that operate during hours of darkness.

6.3.3 Urban Clusters

The default lighting zone for urban clusters as defined by the U.S. Census Bureau is Lighting Zone 2. However, local jurisdictions may designate certain areas as either Lighting Zone 3 or Lighting Zone 4 if it is determined that ambient lighting levels are higher than typical for a rural area. Examples of areas that might be designated Lighting Zone 3 are special commercial districts or areas with special security considerations.

Local jurisdictions also may designate default Lighting Zone 2 areas as Lighting Zone 1, which would establish lower lighting power for outdoor areas with lower surrounding brightness. An example of an area that might be changed to Lighting Zone 1 would include an undeveloped, environmentally sensitive, or predominately residential area within a default Lighting Zone 2 area.

6.3.4 Urban Areas

Lighting Zone 3 is the default for urban areas, as defined by the U.S. Census Bureau. Local jurisdictions may designate areas as Lighting Zone 4 for high-intensity nighttime use, such as entertainment, commercial districts, or areas with special security considerations requiring very high light levels.

Local jurisdictions also may designate default Lighting Zone 3 areas as Lighting Zone 2 or Lighting Zone 1 if deemed appropriate.

Table 6-2: Lighting Zone Characteristics and Rules for Amendments by Local Jurisdictions

Zone	Ambient Illumination	Statewide Default Location	Moving Up to Higher Zones	Moving Down to Lower Zones
A) LZ0	B) Very Low	C) Undeveloped areas of government designated parks, recreation areas, and wildlife preserves.	D) Undeveloped areas of government designated parks, recreation areas, and wildlife preserves can be designated as LZ1 or LZ2 if they are contained within such a zone.	E) Not applicable
F) LZ1	G) Low	H) Rural areas, as defined by the 2010 U.S. Census. These areas include single or dual family residential areas, parks, and agricultural zone districts, developed portion of government designated parks, recreation areas, and wildlife preserves. Those that are wholly contained within a higher lighting zone may be considered by the local government as part of that lighting zone.	I) Developed portion of a government designated park, recreation area, or wildlife preserve, can be designated as LZ2 or LZ3 if they are contained within such a zone. Retail stores, located in residential neighborhood, and rural town centers, as defined by the 2010 U.S. Census, can be designated as LZ2 if the business operates during hours of darkness.	J) Not applicable.
K) LZ2	L) Moderate	M) Urban clusters, as defined by the 2010 U.S. Census. The following building types may occur here: multifamily housing, mixed use residential neighborhoods, religious facilities, schools, and light commercial business districts or industrial zoning districts.	O) Special districts within a default LZ2 zone may be designated as LZ3 or LZ4 by a local jurisdiction. Examples include special commercial districts or areas with special security considerations located within a mixed-use residential area or city center.	P) Special districts may be designated as LZ1 by the local jurisdiction, without any size limits.

Zone	Ambient Illumination	Statewide Default Location	Moving Up to Higher Zones	Moving Down to Lower Zones
		N)		
Q) LZ3	R) Moderately High	S) Urban areas, as defined by the 2010 U.S. Census. T) The following building types may occur here: high intensity commercial corridors, entertainment centers, and heavy industrial or manufacturing zone districts.	U) Special districts within a default LZ3 may be designated as a LZ4 by local jurisdiction for high intensity nighttime use, such as entertainment or commercial districts or areas with special security considerations requiring very high light levels.	V) Special districts may be designated as LZ1 or LZ2 by the local jurisdiction, without any size limits.
W) LZ4	X) High	Y) None	Z) Not applicable.	AA) Not applicable.

Source: Energy Code Table 10-114-A

6.3.5 Determining the Lighting Zone for an Outdoor Lighting Project

Permit applicants may determine the lighting zone for a particular property using the following steps.

For government-designated parks, recreation areas, and wildlife preserves:

- Check with the local jurisdiction having authority over permitting of the property. The local jurisdiction will know if the property is a government-designated park, recreation area, or wildlife preserve, and therefore in default Lighting Zone 0 or 1. The local jurisdiction also may know if the property is contained within the physical boundaries of a lighting zone for which a locally adopted change has been made.

For urban areas, urban clusters, and rural areas:

- The lighting zones for urban areas, urban clusters, and rural areas as well as the legal boundaries of wilderness and park areas are based on the 2010 U.S. Census Bureau boundaries. According to the U.S. Census Bureau, there are two types of urban designations, urbanized areas of 50,000 or more people and urban clusters of at least 2,500 and less than 50,000 people. "Rural" areas encompass all population, housing, and territory not included within an urban area or urban cluster.
- The U.S. Census Bureau website can be used to determine if the property is within Lighting Zone 1 (rural areas), Lighting Zone 2 (urban clusters), or Lighting Zone 3 (urban areas). Using an online map overlay tool provided by the U.S. Census Bureau on tool for geographic overlays at

https://tigerweb.geo.census.gov/tigerweb/, the property address can be entered to look up geography results indicating whether the address is within an urban area ("2010 Census Urbanized Area" layer), urban cluster ("2010 Census Urban Clusters" layer), or rural area (no layer) or move the map over the region of interest. Blue layers represent the boundaries of urban areas. Purple layers represent the boundaries of urbanized clusters. Figure 6-2 shows a screen image of the U.S. Census Bureau online map overlay tool.

Figure 6-2: Example of U.S. Census Bureau Web Tool With Map Overlay

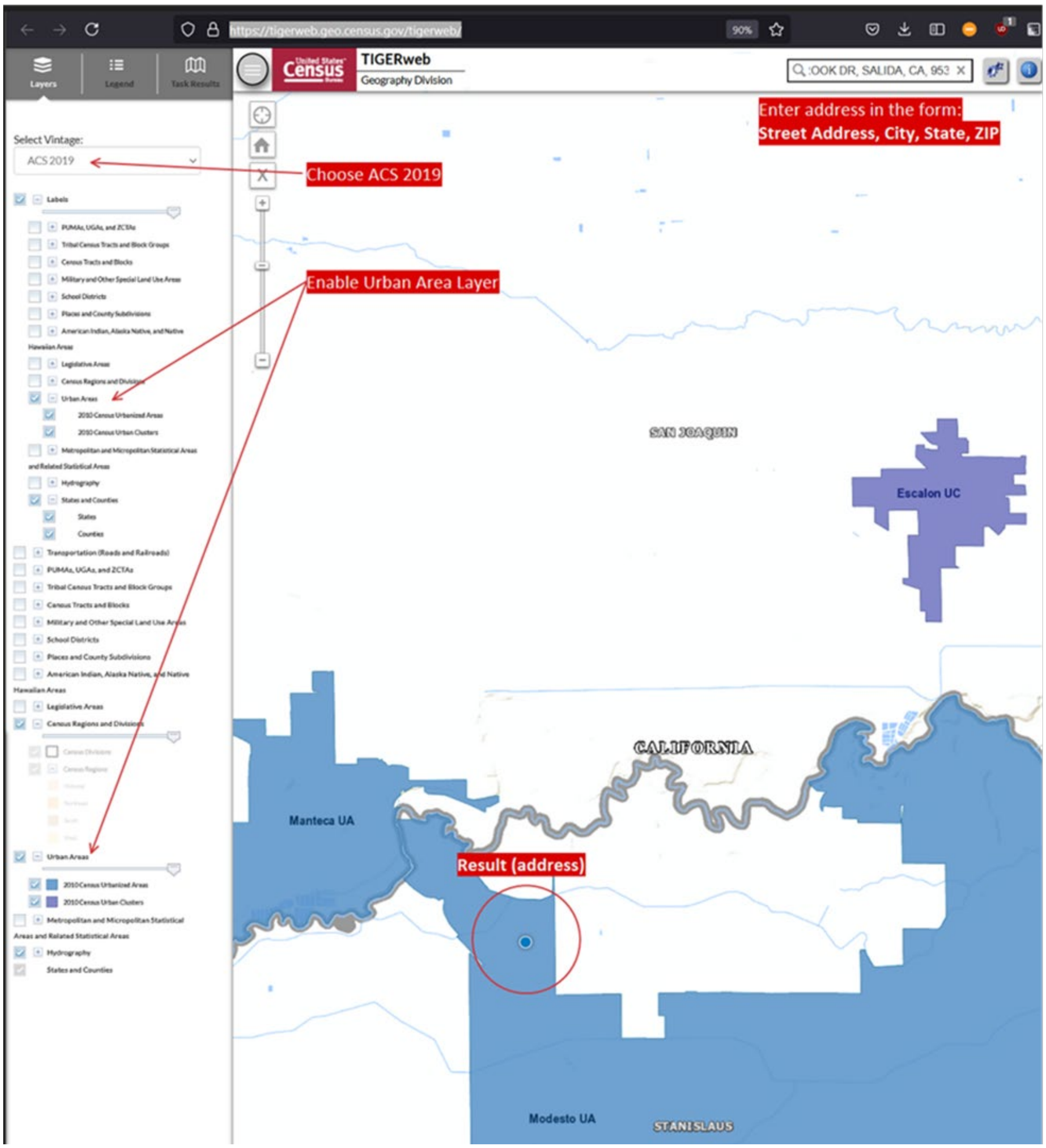


Image Source: U.S. Census Bureau website

6.3.6 Lighting Zone Adjustments by Local Jurisdictions

§10-114
Energy Standards Table 10-114-A

The CEC sets statewide default lighting zones. However, jurisdictions (usually a city or county) may change lighting zones to accommodate local conditions. Local governments may designate a portion of Lighting Zones 2 or 3 as Lighting Zone 3 or 4. The local jurisdiction also may designate a portion of Lighting Zone 3 to Lighting Zone 2 or even Lighting Zone 1. When a local jurisdiction adopts changes to the lighting zone boundaries, it must follow a public process that allows for formal public notification, review, and comment about the proposed change.

6.3.7 Lighting Zone Examples of Using Physical Boundaries

Using metes and bounds is a good method to use for defining the physical boundaries of an adopted lighting zone.

"Metes and bounds" is a system that uses physical features of the local geography, along with directions and distances, to define and describe the boundaries of a parcel of land. The boundaries are described in a running prose style, working around the parcel of the land in sequence, from a beginning point and returning to the same point. The term "mete" refers to a boundary defined by the measurement of each straight run, specified by a distance between the terminal points, and an orientation or direction. The term "bounds" refers to a more general boundary description, such as along a certain watercourse or public roadway.

The following examples use metes and bounds to define the physical boundaries of an adopted lighting zone:

- Properties with frontage on Kennedy Memorial Expressway, between First Avenue and Main Street to a depth of 50 ft. from each frontage property line.
- The area 500 ft. east of Interstate 5, from 500 ft. north of Loomis Ave to 250 ft. south of Winding Way.
- The area of the Sunrise Bike Trail starting at Colfax Avenue and going east to Maple Park, the width of a path which is from the edge of the South Fork of the American River on one side, to 100 ft. beyond the paved bike trail, or to private property lines, whichever is shorter, on the other side.
- The area that is bounded by the Truckee River on the West, Grizzly Lane on the south, Caddis Road on the east, and the boundary of Placer County on the north.

Note: The physical boundaries of a changed lighting zone are not required to coincide with the physical boundaries of a census tract.

Example 6-1: Changing the Default Lighting Zone

Question

I want to have the default outdoor lighting zone for a particular piece of property changed. How do I accomplish that?

Answer

Check with the local jurisdiction having authority over the property and ask them how to petition to have the default outdoor lighting zone officially adjusted.

Mandatory Requirements

The mandatory requirements must be met for all outdoor lighting projects when they are applicable. Mandatory requirements for outdoor lighting are specified in §110.9, §130.0, §130.2, and §130.4. Mandatory requirements include lighting controls devices and system requirements, outdoor lighting controls installation requirements, luminaire shielding, and outdoor lighting control acceptance testing.

6.4.1 Luminaire Shielding and CALGreen BUG Requirements

§130.2(b)

The 2022 Energy Code includes outdoor luminaire shielding requirements based on the luminaire's initial lumen rating. All outdoor luminaires that emit 6,200 initial lumens or greater must comply with backlight, uplight, and glare (BUG) requirements contained in §5.106.8 of the CALGreen Code (Title 24, Part 11).

The BUG ratings assume that the light emitted from the luminaire is providing useful illuminance on the task surfaces rather than scattering the light in areas where the light is not needed or intended, such as toward the sky. These BUG ratings also increase visibility because high amounts of light shining directly into observer's eyes are reduced, thus decreasing glare. Additionally, light pollution into neighbors' properties is reduced. The BUG requirements vary by outdoor lighting zones which are described in section 6.3.

Luminaire manufacturers are aware of the technical details of the BUG ratings and typically provide the BUG ratings for their luminaires in product specifications or cutsheets. In the rare occasions where the luminaire manufacturer does not provide a BUG rating, it can be calculated with outdoor lighting software if the luminaire photometric data is available.

There are exceptions to the luminaire shielding and the BUG rating requirements in CALGreen and the Energy Code.

The following are the exceptions in CALGreen Section 5.106.8: (The information is extracted from the 2022 CALGreen Code):

1. Luminaires that qualify as exceptions in Sections 130.2(b) and 140.7 of the California Energy Code
2. Emergency lighting

3. Building façade meeting the requirements in Table 140.7-B of the California Energy Code, Part 6

- Custom features as allowed by the local enforcing agency, as permitted by Section 101.8 (of the CALGreen Code) Alternate materials, designs and methods of construction
- Luminaires with less than 6,200 initial luminaire lumens.

The following are exceptions in §130.2 of the Energy Code for outdoor lighting applications that are exempted from the luminaire shielding requirements. In some of these applications lighting directed sideways and upwards may be desirable.

- Signs.
- Lighting for building façades, public monuments, public art, statues, and vertical surfaces of bridges.
- Lighting required by a health or life safety statute, ordinance, or regulation that may fail to meet the uplight and glare limits due to application limitations.
- Temporary outdoor lighting that does not persist beyond 60 consecutive days or more than 120 days per year.
- Replacement of existing pole mounted luminaires in hardscape areas that are spaced more than six times the mounting height of the existing luminaires and the replacement luminaire wattage is less than or equal to the wattage of the original luminaires. In addition:

  Where the existing luminaire does not meet the BUG requirements in Section 130.2(b).

  Where no additional poles are being added to the site.

  Where new wiring to the luminaires is not being installed.

- Luminaires that light the public right of way including publicly maintained or utility-maintained roads, sidewalks, or bikeways.

In addition, local ordinance may have a more stringent outdoor lighting BUG requirements than that of the CALGreen Code — the local ordinance would govern the outdoor lighting BUG requirements in that scenario.

Example 6-2:

Question

Which outdoor lighting are exempted from the CALGreen requirements in Section 5.106.8?

Answer

Certain categories of outdoor lighting luminaires are exempted from the light pollution reduction requirements of CALGreen Code Section 5.106.8, and they are as follows.

First, outdoor lighting luminaires with less than 6,200 initial luminaire lumens are exempted.

Second, listed below are additional outdoor lighting luminaires which are also exempted. (Listed below are for a quick reference. For more details, see the box further below.)

- Outdoor lighting with custom features as allowed by Section 101.8 of the California CALGreen Code.
- Outdoor luminaires exempted in §130.2(b) and §140.7 of the California Energy Code.
- Building façade lighting indicated in Table 140.7-B of the California Energy Code.
- Emergency lighting.

Example 6-3:

Question

How do you determine the glare rating for a luminaire located in Lighting Zone 3?

Reference

(Relevant information extracted from the 2022 CALGreen Code and they are included here for reference.)

CALGreen 5.106.8.2 Facing – Glare.

For luminaires covered by Section 5.106.8.1 of the CALGreen Code, if a property line also exists within or extends into the front hemisphere within two mounting heights (2 MH) of the luminaire, then the luminaire shall comply with the more stringent glare rating specified in Table 5.106.8 based on the lighting zone and distance to the nearest point on the nearest property line within the front hemisphere.

CALGreen Table 5.106.8

TABLE 5.106.8 [N]
MAXIMUM ALLOWABLE BACKLIGHT, UPLIGHT AND GLARE (BUG) RATINGS[1,2]

ALLOWABLE RATING	LIGHTING ZONE LZ0	LIGHTING ZONE LZ1	LIGHTING ZONE LZ2	LIGHTING ZONE LZ3	LIGHTING ZONE LZ4
Maximum Allowable Backlight Rating (B)					
Luminaire greater than 2 mounting heights (MH) from property line	N/A	No Limit	No Limit	No Limit	No Limit
Luminaire back hemisphere is 1 – 2 MH from property line	N/A	B2	B3	B4	B4
Luminaire back hemisphere is 0.5 – 1 MH from property line	N/A	B1	B2	B3	B3
Luminaire back hemisphere is less than 0.5 MH from property line	N/A	B0	B0	B1	B2
Maximum Allowable Uplight Rating (U)					
For area lighting[3]	N/A	U0	U0	U0	U0
For all other outdoor lighting, including decorative luminaires	N/A	U1	U2	U3	U4
Maximum Allowable Glare Rating (G)					
Luminaire greater than 2 MH from property line	N/A	G1	G2	G3	G4
Luminaire front hemisphere is 1 – 2 MH from property line	N/A	G0	G1	G1	G2
Luminaire front hemisphere is 0.5 – 1 MH from property line	N/A	G0	G0	G1	G1
Luminaire front hemisphere is less than 0.5 MH from property line	N/A	G0	G0	G0	G1

1. IESNA Lighting Zones 0 are not applicable; refer to Lighting Zones as defined in the *California Energy Code* and Chapter 10 of the *California Administrative Code*.
2. For property lines that abut public walkways, bikeways, plazas and parking lots, the property line may be considered to be 5 feet beyond the actual property line for purpose of determining compliance with this section. For property lines that abut public roadways and public transit corridors, the property line may be considered to be the centerline of the public roadway or public transit corridor for the purpose of determining compliance with this section.
3. General lighting luminaires in areas such as outdoor parking, sales or storage lots shall meet these reduced ratings. Decorative luminaires located in these areas shall meet *U*-value limits for "all other outdoor lighting."

5.106.8.1 Facing – Backlight.

Images Source: California Energy Commission. (The information is extracted from the 2022 CALGreen Code and included here for reference.)

Answer

Start by looking up **Table 5.106.8** of CALGreen Code.

Refer to Column 5 for Lighting Zone 3. The top rows show the backlight rating, the two rows in the middle show the glare rating, and the bottom rows show the uplight rating.

Next, determine the glare rating from the bottom rows and locate the values from Column 5.

See below for a summary of information related to the luminaires in this example for Lighting Zone 3.

Luminaire greater than 2 mounting heights (MH) from property line	Glare rating of G3 or less
Luminaire back/front hemisphere is 1 — 2 MH from property line	Glare rating of G1 or less
Luminaire back/front hemisphere is 0.5 — 1 MH from property line	Glare rating of G1 or less
Luminaire back/front hemisphere is less than 0.5 MH from property line	Glare rating of G0 or less

Images Source: California Energy Commission. (The information is extracted from the 2022 CALGreen Code and included here for reference to the above example.)

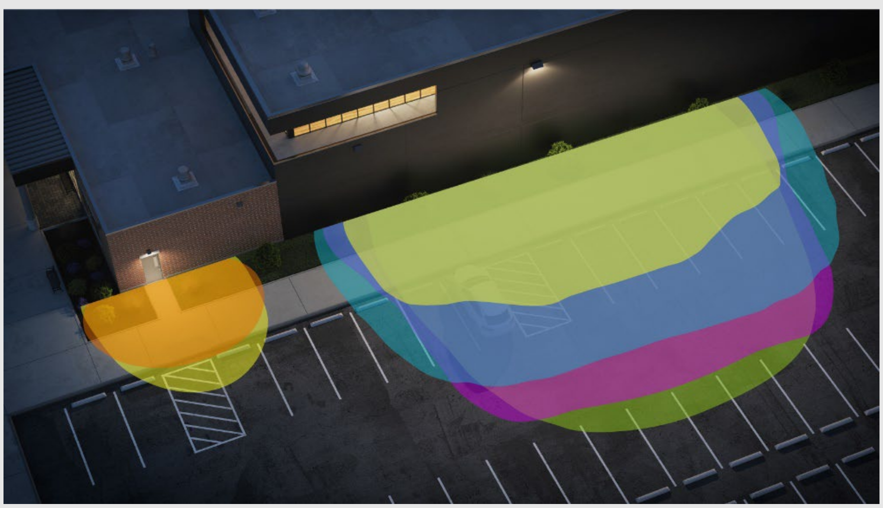
The maximum allowable glare rating for Lighting Zone 3 ranges from G3, G1, and G0 and the glare rating would depend on the location of the luminaire from a property line.

The glare rating is the maximum allowable rating and therefore any rating that is less than the maximum rating is also allowed. For luminaires located greater than two mounting heights from a property line, a luminaire with a glare rating of G3, G2, G1, or G1 meets the requirement.

Example 6-4:

Question

How do you determine glare requirements for the luminaires shown in the pictures below and are located in Lighting Zone 3?



Images Source: courtesy of Lithonia Lighting, a part of Acuity Brands Lighting & Controls.

Answer

First, determine if the luminaire is located within two mounting heights (2 MH) of distance from property line, and refer to Table 5.106.8 of the CALGreen code for the allowable glare rating.

If the distance is greater than 2 MH, the glare rating of the luminaire must be G3 or less (i.e., G2, G1 or G0).

If the distance is within one to two mounting heights (MH) of distance from the property line, the glare rating of the luminaire must be G1 or less (i.e., G0).

Similarly, if the distance is within a half to one mounting height of distance from the property line, the glare rating of the luminaire must be G1 or less (i.e., G0).

If the distance is less than a half mounting height of distance from the property line, the glare rating of the luminaire must be G0.

The above could also be summarized in a tabular format as follows.

Luminaire greater than 2 mounting heights (MH) from property line	Glare rating of G3 or less
Luminaire back/front hemisphere is 1 — 2 MH from property line	Glare rating of G1 or less
Luminaire back/front hemisphere is 0.5 — 1 MH from property line	Glare rating of G1 or less
Luminaire back/front hemisphere is less than 0.5 MH from property line	Glare rating of G0 or less

Images Source: California Energy Commission. (The information is extracted from the 2022 CALGreen Code Table 150.6.8 and included here for reference to the above example.)

Example 6-5:

Question

How do you determine backlight requirements for the luminaire shown in the picture below and the luminaires are located in Lighting Zone 3?

Images Source: courtesy of Lithonia Lighting, a part of Acuity Brands Lighting & Controls.

Reference

(This information below is extracted from the 2022 CALGreen Code and included here for reference.)

CALGreen 5.106.8.1 Facing — Backlight

Luminaires within two mounting heights (2 MH) of a property line shall be oriented so that the nearest property line is behind the fixture, and shall comply with the backlight rating specified in Table 5.106.8 based on the lighting zone and distance to the nearest point of that property line.

Exception: Corners. If two property lines (or two segments of the same property line) have equidistant points to the luminaire, then the luminaire may be oriented so that the intersection of the two lines (the corner) is directly behind the luminaire. The luminaire shall still use the distance to the nearest point(s) on the property lines to determine the required backlight rating.

CALGreen Table 5.106.8

TABLE 5.106.8 [N]
MAXIMUM ALLOWABLE BACKLIGHT, UPLIGHT AND GLARE (BUG) RATINGS[1,2]

ALLOWABLE RATING	LIGHTING ZONE LZ0	LIGHTING ZONE LZ1	LIGHTING ZONE LZ2	LIGHTING ZONE LZ3	LIGHTING ZONE LZ4
Maximum Allowable Backlight Rating (B)					
Luminaire greater than 2 mounting heights (MH) from property line	N/A	No Limit	No Limit	No Limit	No Limit
Luminaire back hemisphere is 1 – 2 MH from property line	N/A	B2	B3	B4	B4
Luminaire back hemisphere is 0.5 – 1 MH from property line	N/A	B1	B2	B3	B3
Luminaire back hemisphere is less than 0.5 MH from property line	N/A	B0	B0	B1	B2
Maximum Allowable Uplight Rating (U)					
For area lighting[3]	N/A	U0	U0	U0	U0
For all other outdoor lighting, including decorative luminaires	N/A	U1	U2	U3	U4
Maximum Allowable Glare Rating (G)					
Luminaire greater than 2 MH from property line	N/A	G1	G2	G3	G4
Luminaire front hemisphere is 1 – 2 MH from property line	N/A	G0	G1	G1	G2
Luminaire front hemisphere is 0.5 – 1 MH from property line	N/A	G0	G0	G1	G1
Luminaire front hemisphere is less than 0.5 MH from property line	N/A	G0	G0	G0	G1

1. IESNA Lighting Zones 0 are not applicable; refer to Lighting Zones as defined in the *California Energy Code* and Chapter 10 of the *California Administrative Code*.
2. For property lines that abut public walkways, bikeways, plazas and parking lots, the property line may be considered to be 5 feet beyond the actual property line for purpose of determining compliance with this section. For property lines that abut public roadways and public transit corridors, the property line may be considered to be the centerline of the public roadway or public transit corridor for the purpose of determining compliance with this section.
3. General lighting luminaires in areas such as outdoor parking, sales or storage lots shall meet these reduced ratings. Decorative luminaires located in these areas shall meet *U*-value limits for "all other outdoor lighting."

5.106.8.1 Facing – Backlight.

(The above information is extracted from the 2022 CALGreen Code and included here for reference.)

Answer

First, if the luminaire is located at more than two mounting height (2 MH) of distance from the property line, there is no mandatory backlight rating (no limit on backlight) for the luminaire.

For a luminaire located within two mounting height (2 MH) of distance from the property line and that is not exempt, the luminaire must comply with the backlight rating listed in Table 5.106.8.

For a luminaire located in Lighting Zone 3 (LZ3) and within one to two mounting heights (MH) of distance from the property line, the backlight rating of the luminaire must be B4 or less (i.e., B3, B2, B1 or B0).

For the same luminaire in LZ3 and within a half to one mounting height of distance from the property line, the backlight rating of the luminaire must be B3 or less (i.e., B2, B1 or B0).

For the same luminaire in LZ3 and located less than a half mounting height of distance from the property line, the backlight rating of the luminaire must be B1 or less (i.e., B0).

The above information could also be summarized in a tabular format below.

Luminaire greater than 2 mounting heights (MH) from property line	No limit
Luminaire back hemisphere is 1 - 2 MH from property line	B4 or less
Luminaire back hemisphere is 0.5 - 1 MH from property line	B3 or less
Luminaire back hemisphere is less than 0.5 MH from property line	B1 or less

(This information is extracted from the 2022 CALGreen Code.)

Example 6-6: Defining the Property Line for the Purpose of BUG Rating Compliance

Question

Where is the property line if the area under construction is located next to a public road?

Answer

For a property line that abuts a public roadway or transit corridor, the property line may be the centerline of the public roadway or transit corridor.

For a property lines that abuts a public walkway, bikeway, plaza, or parking lot, the property line may be 5 feet beyond the actual property line.

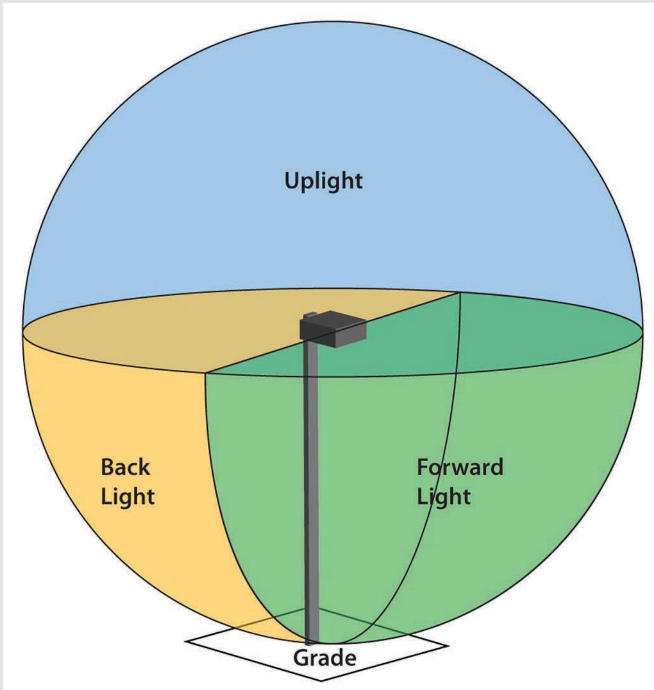
Example 6-7: Luminaire Classification for Outdoor Luminaires

Question

What is the IES BUG system for outdoor luminaires?

Answer

Illuminating Engineering Society (IES) published the technical memorandum ’Luminaire Classification for Outdoor Luminaires’ (document TM-15-20). This document defines three-dimensional regions of analysis for exterior luminaires and further establishes zonal lumen limits for these regions as part of a larger method of categorizing outdoor lighting equipment into backlight, uplight, and glare components. Collectively, the three components are referred to as the BUG system.



The Three Primary Solid Angles of the Luminaire Classification System for Outdoor Luminaires

Image Source: Illuminating Engineering Society (image from ANSI/IES TM-15-20)

The zonal lumen limits per secondary solid angles for uplight and glare are based upon the methodology found in TM-15. The lighting zone in which the project is located determines the maximum zonal lumens for backlight, uplight, and glare.

To comply with this mandatory measure, the luminaire must not exceed the maximum zonal lumen limits for each secondary solid angle region per lighting zone. The zonal lumen values in a photometric test report must include any tilt or other nonlevel mounting condition of the installed luminaire. The BUG rating requirements can be found in CALGreen Code §5.106.8.

The BUG rating for luminaires may be determined with outdoor lighting software or by contacting the manufacturer. There is also software available to produce a BUG rating for a tilted luminaire condition (which is not a typical circumstance for most applications). Since the California BUG limits and calculation procedures match the IES, no deviation from the IES BUG rating is necessary.

Example 6-8: Wallpacks and Zonal Lumen Limits

Question

A new parking lot adjacent to a building is being designed to be illuminated by wall packs rated at 7,000 initial luminaire lumens. The wall packs are mounted on the side of the building, and their main purpose is parking lot illumination. But they are also illuminating the façade of the building. Do these wall packs have to meet the backlight, uplight, and glare (BUG) rating limits?

Answer

Yes, these 7,000 lumen wall packs will have to meet the BUG rating requirements because the main purpose is parking lot illumination. Luminaire mounting methods or locations do not necessarily determine the purpose of the illumination. Define the function of the luminaire by determining what the majority of the light is striking. For a typical wall pack, 80% or more of the light is likely striking the parking lot or sidewalk in front of the building, and only 20% or less on the façade, so BUG rating limits apply.

Each luminaire must be appropriately assigned to the function area that it is illuminating, whether it is mounted to a pole, building, or other structure. Only luminaires that are rated less than 6,200 initial luminaire lumens or outdoor lighting applications that are exempt, are not required to meet the backlight, uplight, and glare (BUG) requirements in the Energy Code.

Example 6-9: Tilted Luminaires Meeting the BUG Requirements

Question

If a low BUG rating luminaire is mounted at a tilt, does it still meet the BUG requirements?

Answer

It depends. Luminaires that meet the zonal lumen limits when mounted at 90° to nadir may or may not comply with the BUG rating limits when they are mounted at a tilt.

For a tilted luminaire to meet this requirement, a photometric test report must be provided showing that the luminaire meets the zonal lumen limits at the proposed tilt. There are lighting design software available to calculate a BUG rating for a tilted luminaire, or this can be provided by the manufacturer.

6.4.2 Requirements for Outdoor Lighting Controls

§130.2(c)

The primary requirements for outdoor lighting controls are as follows:

1. Daylight Availability: All outdoor lighting shall be automatically controlled so that lighting is off when daylight is available (§130.2[c]1).

2. Automatic Scheduling Controls: All outdoor lighting shall be automatically controlled by a time-based scheduling control (§130.[c]2).
3. Motion-Sensing Controls: Outdoor luminaires greater than 40 watts and mounted 24 ft or less above the ground shall be controlled by motion-sensing controls. This applies to luminaires providing general hardscape lighting, outdoor sales lot lighting, vehicle service station hardscape lighting, or vehicle service station canopy lighting (§130.2[c]3).

Outdoor lighting control requirements do not apply to any of the following lighting applications:

1. Lighting where a health or life safety statute, ordinance, or regulation prohibits outdoor lighting to be turned OFF or reduced.
2. Lighting in tunnels required to be illuminated 24 hours per day and 365 days per year.

Example 6-10: Circuiting of Non-Outdoor Lighting Load

Question

Can irrigation controllers be on the same power circuit as lighting?

Answer

The outdoor lighting load may be on the same circuit with other electrical loads if the outdoor lighting load is independently controlled from all other electrical loads.

A. Daylight Availability

§130.2(c) 1

All installed outdoor lighting must be controlled by a photocontrol, astronomical time-switch control, or other controls that automatically turns off the outdoor lighting when daylight is available.

- A photocontrol measures the amount of ambient light outdoors. When the light level outside is high enough to indicate that it is daytime, the control turns lighting off.
- Astronomical time-switch controls require an initial setup of the time clock device, which may include the entry of the current date and time (and time zone), site location (by longitude and latitude), and whether daylight saving time is applicable. The clock calculates sunrise and sunset times (which vary by location and day of the year) and turns lighting off at sunrise and on at sunset.

Astronomical time switches are time-based controls that can be used to meet the daylight availability and automatic scheduling control requirements.

B. Automatic Scheduling Controls

§130.2(c)2

All installed outdoor lighting shall be controlled by an automatic scheduling control capable of reducing lighting power by 50 to 90 percent and separately capable of turning lighting off when not needed according to a schedule.

Further, automatic scheduling controls are required to have the capability of programming at least two nighttime periods (a scheduled occupied period and a scheduled unoccupied period) with different light levels, if desirable by the building design and operation.

Automatic scheduling controls provide flexibility to accommodate changes in building operation. If different operating schedules or different lighting levels are desired, the settings of the automatic scheduling controls can be adjusted.

There are applications in which there are benefits to employ both motion-sensing controls and automatic scheduling controls. Some lighting applications will require both control types.

Example 6-11: Using Automatic Scheduling Controls Plus Some Other Controls

Question

Can motion-sensing controls be used together with automatic scheduling controls?

Answer

Some applications require the installation of motion-sensing controls. For these applications, automatic scheduling controls are required in addition to motion-sensing controls. During the scheduled occupied period, motion-sensing controls can detect occupancy of an outdoor space and turn on or reduce lighting based on the occupancy of the space. During the scheduled unoccupied period, the automatic scheduling control can turn off all lighting.

Example 6-12: Using Automatic Scheduling Controls for Buildings That Operate 24x7

Question

Is the automatic scheduling control requirement applicable to a building occupied 24 hours per day, seven days per week?

Answer

Yes, automatic scheduling controls are required for buildings that are occupied 24 hours per day, seven days per week.

Business activities can change over time as business models and hours of operation evolve. The required nighttime periods of a scheduled occupied period and a scheduled unoccupied period are decided by the building owner or the building operator, as appropriate, to suit the business needs.

Acceptance Tests Required for Automatic Scheduling Controls

Outdoor automatic scheduling controls are required to have acceptance testing conducted to confirm the appropriate schedules are programmed and the controls operate per the programmed schedule. The acceptance test procedures are detailed in Reference Nonresidential Appendix NA7.8.5. Refer to Section 6.7.5 of this manual for details about outdoor lighting controls acceptance test.

C. Motion-Sensing Controls

§130.2(c)3

Outdoor luminaires greater than 40 watts, where the bottom of the luminaire is mounted 24 ft. or less above the ground, shall be operated with motion-sensing controls if they are used in the following applications:

1. General hardscape lighting including parking lot lighting
2. Vehicle service station hardscape lighting and canopy lighting
3. Wall pack lighting installed for building façade, ornamental hardscape, or outdoor dining lighting

The motion sensing controls shall:

1. Be capable of reducing the lighting power of each luminaire by at least 50 percent and no more than 90 percent, and separately be capable of turning the luminaire off during unoccupied periods.
2. Be capable of reducing the lighting to the dim or off state within 15 minutes of vacancy detection and turning the lighting back on upon occupancy.
3. Control no more than 1,500 watts of lighting power by a single sensor or as a single zone.

Exceptions to All Motion-Sensing Control Requirements

The motion control requirements do not apply to applications listed as exceptions to §140.7(a). These applications exempted from the motion controls requirements of §130.2(c)3 when more than 50 percent of the light fails in the application. The applications include temporary outdoor lighting, lighting for public roadways, and lighting for public monuments. The complete listing can be found in Section 140.7(a). Exempt lighting applications are also provided on the rightmost column of Table 6-1.

In addition, luminaires serving the following applications are not required to have motion-sensing controls:

1. Lighting for outdoor sales frontage, building façades, ornamental hardscape, and outdoor dining (wall pack luminaires in these applications must meet motion sensor requirements).
2. Luminaires with a rated wattage of 40 watts or less.
3. Wall pack luminaires and luminaires mounted greater than 24 feet above grade.

4. Lighting subject to health or life safety statute, ordinance, or regulation may have a minimum time-out period longer than 15 minutes or a minimum dimming level above 50 percent.

Acceptance Tests Required for Motion Sensing Controls

Motion-sensing controls are required to have an acceptance testing conducted to confirm that the sensor can sense activity within the detection zone and turn lighting on when occupancy is detected and reduce or turn lighting off within 15 minutes of vacancy detected. The acceptance test procedures are detailed in Reference Nonresidential Appendix NA7.8.1. Refer to Section 6.7.5 of this manual for details about outdoor lighting controls acceptance test.

6.4.3 Lighting Control Functionality

§110.9(b)

All installed lighting control device and systems must meet the functionality requirements in §110.9(b). In addition, all components of a lighting control system installed together shall meet all applicable requirements for the application for which they are installed as required in §130.0 through §130.5, §140.6 through §140.8, §141.0, and §150.0(k).

Designers and installers should review features of their specified lighting control products for meeting the requirements of §110.9(b) as part of the code compliance process.

D. Time-Switch Lighting Controls

Time-switch lighting control products shall provide the functionality listed in §110.9(b)1 of the Energy Code.

E. Daylighting Controls

Daylighting control products shall provide the functionality listed in §110.9(b)2 of the Energy Code.

F. Dimmers

Dimmer products shall provide the functionality listed in §110.9(b)3 of the Energy Code.

G. Occupant-Sensing Controls

Occupant-sensing control products for outdoor lighting applications (including motion sensors) shall provide the functionality listed in §110.9(b)4 and §110.9(b)6 of the Energy Code.

One important feature of occupant sensing controls is that it must automatically reduce lighting or turn the lighting off within 20 minutes after the area has been vacated.

Example 6-13: Designer Responsibility for Lighting Control Devices and Systems

Question

What is the responsibility of the designer regarding using lighting control products that meet the functionality requirements in §110.9(b)?

Answer

It is the responsibility of the designer to specify only lighting control products that meet the functionality requirements in §110.9(b).

Example 6-14: Installer Responsibility for Lighting Control Devices and Systems

Question

What is the responsibility of the installer regarding using lighting control products that meet the functionality requirements in §110.9(b)?

Answer

It is the responsibility of the installer to install only lighting control products that meet the functionality requirements in §110.9(b). It is also the responsibility of the installer to sign the installation certificate.

Prescriptive Measures

6.5.1 Outdoor Lighting Power Compliance

An outdoor lighting installation complies with the Energy Code if the actual outdoor lighting power is no greater than the allowed outdoor lighting power. This section describes the procedures and methods for complying with §140.7.

The allowed outdoor lighting power is the sum of the general hardscape allowance, and additional lighting power allowances.

- The general hardscape allowance is for luminaires that provide general hardscape lighting to hardscape areas such as parking lots, walkways, roadways, and other improved areas that are illuminated. The general hardscape allowance is calculated using the general hardscape area and perimeter length.
- Additional lighting power allowances are used for specific outdoor lighting applications such as outdoor dining areas, building entrances and exits, and outdoor sales frontage. These allowances are calculated per application (W per occurrence), per unit length (W/ft.), or per area (W/ft^2).

The allowed lighting power must be calculated for the general hardscape lighting of the site and for specific applications if desired. (See §140.7[d])

The allowed outdoor lighting power is calculated by lighting zone as defined in §10-114. Local governments may amend lighting zones in compliance with §10-114. See Section 6.4.1 for more information about amending outdoor ordinances by local jurisdictions.

The actual power of outdoor lighting is the total wattage of all nonexempt lighting systems that will be installed (including ballast, driver, or transformer loss) (See §140.7[c]). The wattage of outdoor luminaires must be determined in accordance with §130.0(c) or Reference Nonresidential Appendix NA8. See Section 5.3 for more information about determining luminaire wattage.

H. Allowed Lighting Power

The Energy Code establish maximum allowed outdoor lighting power that can be installed. The allowed outdoor lighting power must be determined according to the outdoor lighting zone in which the site is located. See Section 6.3 for more information about outdoor lighting zones.

An outdoor lighting installation complies with the lighting power requirements if the actual outdoor lighting power installed is no greater than the allowed outdoor lighting power calculated under §140.7(d) and complies with certain stipulations associated with specific special application allowances. The allowed lighting power shall be the combined total of the sum of the general hardscape lighting allowance determined in accordance with §140.7(d)1, and the sum of the additional lighting power allowance for specific applications determined in accordance with §140.7(d)2.

I. Illuminated Area

With indoor lighting applications, the entire floor area is illuminated for the determining the allowed lighting power. However, for outdoor lighting applications, the number of luminaires, mounting heights and layout affect the presumed illuminated area and, therefore, the allowed lighting power.

The area of the lighting application may not include any areas on the site that are not illuminated. The area beyond the last luminaire is considered illuminated only if it is located within 5 mounting heights of the nearest luminaire.

In plan view of the site, the “illuminated area” is defined as any hardscape area within a square pattern around each luminaire or pole that is 10 times the luminaire mounting height, with the luminaire in the middle of the pattern. Another way to envision this is to consider an illuminated area from a single luminaire as the area that is 5 times the mounting height in four directions.

Illuminated areas shall not include any area that is obstructed by any other structure, including a sign, within a building, or areas beyond property lines.

The primary purpose for validating the illuminated area is to exclude any areas that are not illuminated. Areas that are illuminated by more than one luminaire shall not be double-counted. An area is either illuminated or it is not illuminated.

When luminaires are located farther apart (more than 10 times their mounting height apart), then the illuminated area stops at 5 times the mounting height of each luminaire.

Planters and small landscape areas are included within the general hardscape area if the short dimension of the inclusion is less than 10 ft. wide, and the inclusion is bordered on at least three sides.

Landscape areas that are greater than 10 ft. wide in the short dimension are excluded from the general hardscape area calculation, but the perimeter of these exclusions may be included.

6.5.2 General Hardscape Lighting Power Allowance

The general hardscape allowance is calculated based on the general hardscape area, perimeter length and lighting zone that the property is located in.

J. Calculation of Allowed Lighting Power — General Hardscape Lighting Power Allowance

Hardscape is defined in §100.1 as an improvement to a site that is paved and has other structural features, including, but not limited to, curbs, plazas, entries, parking lots, site roadways, driveways, walkways, sidewalks, bikeways, water features and pools, storage or service yards, loading docks, amphitheaters, outdoor sales lots, and private monuments and statuary.

Determine the general hardscape lighting power allowances as follows:

1. The general hardscape area of a site shall include parking lot(s), roadway(s), driveway(s), sidewalk(s), walkway(s), bikeway(s), plaza(s), bridge(s), tunnel(s), and other improved area(s) that are illuminated. In plan view of the site, determine the illuminated hardscape area, which is defined as any hardscape area that is within a square pattern around each luminaire or pole that is 10 times the luminaire mounting height with the luminaire in the middle of the pattern, less any areas that are within a building, beyond the hardscape area, beyond property lines, or obstructed by a structure. The illuminated hardscape area shall include portions of planters and landscaped areas that are within the lighting application and are less than or equal to 10 feet wide in the short dimensions and are enclosed by hardscape or other improvement on at least three sides. Multiply the illuminated hardscape area by the area wattage allowance (AWA) from Table 6-4 (Table 140.7-A) for the appropriate lighting zone.
2. Determine the perimeter length of the general hardscape area. The total hardscape perimeter is the length of the actual perimeter of the illuminated

hardscape on the property. It shall not include portions of hardscape that are not illuminated according to §140.7(d)1A. Multiply the hardscape perimeter by the linear wattage allowance (LWA) for hardscape from Table 6-4 (Table 140.7-A) for the appropriate lighting zone. Generally, if there is an enclosed exclusion in the area AWA calculation, the perimeter may be included in the LWA calculation.

3. The perimeter length for hardscape around landscaped areas and permanent planters shall be determined as follows:
    a. Landscaped areas completely enclosed within the hardscape area, and with a width or length a minimum of 10 feet wide, shall have the perimeter of the landscaped areas or permanent planter added to the hardscape perimeter length.
    b. Landscaped areas completely enclosed within the hardscape area, and with a width or length less than 10 feet wide, shall not be added to the hardscape perimeter length.
    c. Landscaped edges that are not abutting the hardscape shall not be added to the hardscape perimeter length.
4. Determine the initial wattage allowance (IWA). The IWA can be used one time per site. The purpose is to provide additional watts for small sites, or for odd hardscape geometries. Add the IWA for general hardscape lighting from Table 6-4 (Table 140.7-A) for the appropriate lighting zone.
5. The general hardscape lighting allowance shall be the sum of the allowed watts determined from (1), (2) and (3) above.

Refer to Figure 6-1 for a concept layout of the general hardscape lighting allowance for area, and perimeter, as well as initial wattage allowance.

Table 6-3 (Table 140.7-A): General Hardscape Lighting Power Allowance

Type of Power Allowance	Lighting Zone 03	Lighting Zone 13	Lighting Zone 23	Lighting Zone 33	Lighting Zone 43
Area Wattage Allowance (AWA)	No allowance[1]	0.016 W/ft^2	0.019 W/ ft^2.	0.021 W/ft^2	0.024 W/ ft^2
Linear Wattage Allowance (LWA)	No allowance[1]	0.13 W/lf	0.15 W/lf	0.20 W/lf	0.29 W/lf
Initial Wattage Allowance (IWA)	No allowance[1]	150 W	200 W	250 W	320 W

Footnotes to Table:

[1] Continuous lighting is explicitly prohibited in Lighting Zone 0. A single luminaire of 15 Watts or less may be installed at an entrance to a parking area, trail head, fee payment kiosk, outhouse, or toilet facility, as required to provide safe navigation of the site infrastructure. Luminaires installed shall meet the maximum zonal lumen limits as specified in 130.2(b).

[2] RESERVED.

[3] Narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm – as mandated by local, state, or federal agencies to minimize the impact on local, active professional astronomy or nocturnal habitat of special local fauna – shall be allowed a 2.0 lighting power allowance multiplier.

Table 140.7-A from the Energy Standards

The allowed lighting power for general hardscape lighting is calculated using the following components:

1. Area wattage allowance (AWA), which is expressed in watts per sq. ft.
2. Linear wattage allowance (LWA), which is expressed in watts per linear foot.
3. Initial wattage allowance (IWA), which is a flat allowance for each property and is expressed in watts.

To determine the total allowed power for general hardscape lighting, use the equation:

General Hardscape Lighting Power Allowance = (Hardscape Area x AWA) + (Perimeter Length of Hardscape Area x LWA) + IWA

Example 6-15: Outdoor Lighting for Healthcare Facilities

Question

Is the parking lot outside of a healthcare facility ("I" occupancy) regulated by the Energy Code?

Answer

Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) must comply with California Energy Code including the outdoor lighting requirements for all outdoor areas of healthcare facilities. For outdoor lighting, a licensed healthcare facility must meet the outdoor lighting power requirements as specified in §140.7 as well as the outdoor lighting control requirements in §130.2.

Example 6-16: Hardscape Materials for Parking Lots

Question

Our overflow parking lot is covered with gravel. Is this parking lot considered "hardscape," and must it comply with the Energy Code?

Answer

Yes, parking lots covered with gravel, or any other material used to enhance the surface to accommodate parking or travel, such as pavers, asphalt, cement, deck board, or other pervious or impervious materials are considered hardscape and must comply with the requirements for hardscape areas. Note that the updates to 140.7-A now cover all hardscape materials to the same power allowances.

Example 6-17: Power Allowance for a Parking Lot

Question

In a parking lot in front of a retail store, we are not using the full general lighting power allowed according to Table 140.7-A. Can we use the remaining allowance to illuminate the building entrance and the walkways near the store to a higher level?

Answer

Yes. Because the general hardscape power allowance is tradable, you may use the unused portion of the power allowance from the parking lot to increase the illumination levels for other lighting applications, including building entrance and walkway areas.

Example 6-18: Calculating the Illuminated Area of a Parking Lot

Question

A parking lot is illuminated by five cut-off wall packs mounted to an adjacent building. The parking lot extends 100 ft. from the building. The luminaires are mounted at a height of 15 ft. above the ground and spaced 50 ft. apart. How large is the illuminated area?

Answer

The illuminated area extends a distance equal to five times the mounting height in three directions. (The fourth direction is not counted because it is obstructed by the building.) The illuminated area, therefore, extends from the building 75 ft. The total illuminated area is 75 ft. x 350 ft. or 26,250 $ft.^2$

Example 6-19: Calculating the Illuminated Area

Question 1

If a -ole mounted luminaire has a height of 15 ft., what are the dimensions of the illuminated area used for power calculations?

Answer 1

The illuminated area is defined as any area within a square pattern around each luminaire or pole that is 10 times the luminaire mounting height, with the luminaire in the middle of the pattern. It does not include any area that is within a building, under a canopy, beyond property lines, or obstructed by a sign or structure. Therefore, for a 15 ft. pole-mounted luminaire, the area will be described by a square that is 150 ft. (15 ft. x 10) on each side, or 22,500 ft^2 (150 ft. x 150 ft.), minus areas that are beyond the property line or other obstructions.

Question 2

If two poles are separated by a distance greater than 10 times the mounting height, will all of the square footage between them be included in the general hardscape area?

Answer 2

In most applications, such as parking lots, these square patterns will typically overlap, so the entire area of the parking lot between poles will typically be included in the general hardscape area when determining the lighting power budget. However, if the poles are so far apart that they exceed 10 times the mounting height of the luminaires on the poles, and the coverage squares do not overlap, then the nonilluminated areas between poles cannot be included in the general hardscape area.

Example 6-20: Calculating the Power Allowance for a Parking Lot

Question

The parking lot illustrated below has two luminaires that are mounted at a height of 25 ft. What is the illuminated hardscape area and what is the general hardscape lighting power allowance? The lot is in Lighting Zone 3.

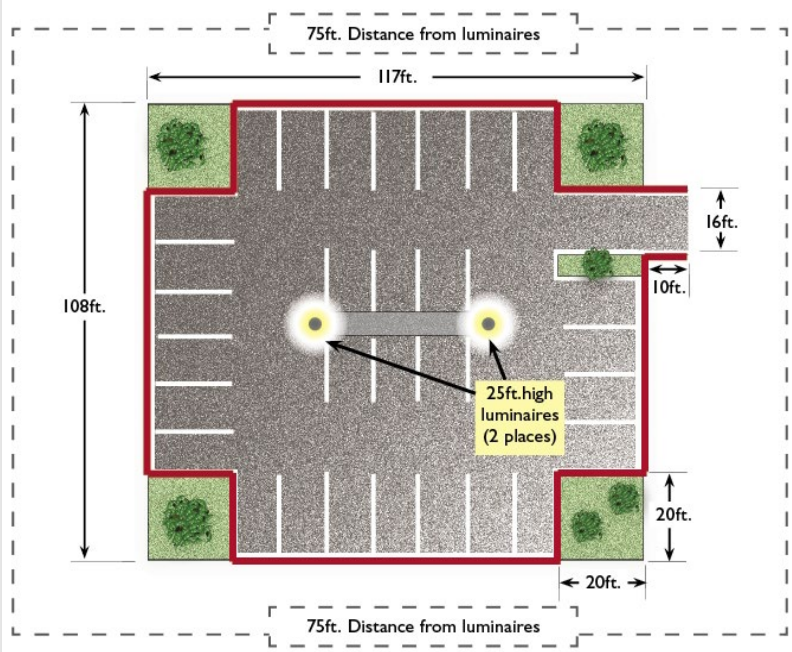


Image Source: California Energy Commission

Answer

The poles are 40 ft. apart, and using the 10 times mounting height rule, the illuminated area can be as large as 250 ft. by 290 ft. The boundary of this illuminated area extends beyond the edges of the parking lot as well as the entrance driveway, so the entire paved area is considered illuminated. The landscaped island in middle and peninsula below the entrance driveway are less than 10 ft. wide, so they are included as part of the illuminated area, but not part of the hardscape perimeter. The landscaped cutouts (20 x 20 ft.) in the corners of the parking lot are bound by pavement on only two sides so they are not included. The total paved area is 11,196 sq. ft. [(12,636 sq. ft. + 160 sq. ft. (driveway) – 1,600 sq. ft (cutouts)]. The perimeter of the hardscape is 470 ft. [(2 x 77 ft.) + (2 x 68 ft.) + (8 x 20 ft.) + (2 X10 ft.)].

Three allowances make up the general hardscape allowance: Area, Linear, and Initial. All allowances are based on Lighting Zone 3 and found in Table 6-3 (Table 140.7-A of the Energy Code).

The area wattage allowance is equal to 235.1 W.

The linear wattage allowance is equal to 94 W.

The initial wattage allowance (IWA) is 250 W for the entire site.

The sum of these three allowances gives a total wattage allowance for the site of 579.1 W.

The calculations are tabulated below.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Initial	250 W	-	250 W
Area	0.021 W/sq. ft.	11,196 sq. ft.	235.1 W
Perimeter	0.2 W/LF	470 ft.	94 W
-	-	**Total Power Allowance:**	**579.1 W**

Example 6-21: General Hardscape Surface Question

Question

Before the 2022 Energy Code, Title 24-2019 allowed a higher lighting power allowance for concrete hardscape surface. If I have a concrete plaza, what is the allowed lighting power allowance I should use for Title 24-2022? The plaza is 115 ft. long and 105 ft. wide in a Lighting Zone 3 location.

Answer

The distinction between different surface material types was removed in Title 24-2022. The lighting power allowance will be based on the Lighting Zone of the project location.

For a plaza located in Lighting Zone 3 the hardscape area must first be calculated. The general hardscape area is 115 ft. x 105 ft. or 12,075 sq. ft. The linear perimeter of this hardscape is the sum of the sides 115 ft. + 105 ft. + 115 ft. + 105 ft. or 440 ft.

Three allowances make up the total power allowance: Area, Linear, and Initial.

However, the initial wattage allowance applies one time to the entire site. It will be considered for usage for this plaza assuming that there is no associated parking lot or other general hardscape area. All allowances are based on the general hardscape Lighting Zone 3 application and can be found in Table 6-3 (Table 140.7-A of the Energy Code).

The initial wattage allowance is equal to 250 W.

The area wattage allowance is equal to 253.6 W.

The linear wattage allowance is equal to 88.0 W.

The sum of these allowances gives a total wattage allowance for the plaza of 591.6 W.

The calculation can also be tabulated as below.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Initial	250 W	-	250 W
Area	0.021 W/sq. ft	12,075 sq. ft.	253.6 W

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Perimeter	0.2 W/LF	615 ft.	88 W
-	-	**Total Power Allowance:**	**591.6 W**

Example 6-22: Calculating the Power Allowance for a Roadway

Question

A 300-ft.-long, 15-ft.-wide roadway leads through a wooded area to a hotel entrance in Lighting Zone 2, and the owner wants to light the roadway with luminaires mounted at a height of 20 ft. What is the allowed lighting power for this roadway with asphalt surface?

Answer

The hardscape area for the roadway must first be calculated. If the entire roadway will be lit, then the 20 ft. poles will not be spaced more than 200 ft. apart and not more than 100 ft. from the ends of the roadway. (Lighted area is 10 times the pole height.) The hardscape area therefore is 15 ft. x 300 ft. or 4,500 sq. ft. The linear perimeter of this hardscape is the sum of the sides (not including the side that connects to the larger site) 300 ft. + 15 ft. + 300 ft. or 615 ft.

Three allowances make up the total power allowance: area, linear, and initial. However, the initial wattage allowance applies one time to the entire site. It is not considered for usage for this roadway piece which would only be one small part of the site. All allowances are based on Lighting Zone 2 and can be found in Table 6-4 (Table 140.7-A of the Energy Code).

The area wattage allowance is equal to 85.5 W.

The linear wattage allowance is equal to 92.3 W.

The sum of these allowances gives a total wattage allowance for the roadway of 177.8 W.

The calculation is tabulated below.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Initial, Hardscape	200 W	-	not used
Area, Hardscape	0.019 W/sq. ft	4,500 sq. ft.	85.5 W
Perimeter, Hardscape	0.15 W/LF	615 ft.	92.3 W
-	-	**Total Power Allowance:**	**177.8 W**

Example 6-23: Flagpole Lighting

Question

Is the lighting power for a flagpole exempt from the 2022 Energy Code?

Answer

Yes. Lighting for a flagpole is considered lighting for a public monument. As described in the exceptions to §140.7(a), lighting power for public monuments is exempt from §140.7 of the 2022 Energy Code. Note that while the power is exempt, this lighting is still subject to the applicable control requirements of §130.2(a), §130.2(c)1, and §130.2(c)2 of the 2022 Energy Code.

Example 6-24: Lighting for Private Streets

Question

Does street lighting inside a gated community with private streets have to meet any lighting requirements?

Answer

Yes. Lighting of private streets must meet the nonresidential outdoor lighting requirements. There are no exceptions to §140.7(a) for private streets. The lights must meet all applicable sections of the nonresidential lighting requirements. (The third exception to §140.7(a) is specific to public streets.)

Example 6-25: Lighting Control Requirements for Outdoor Lighting Exempt From §140.7(a)

Question

For outdoor lighting, if lighting is excluded from the outdoor power limitations per the exceptions to §140.7(a), is that lighting also excluded from the outdoor lighting control requirements of §130.2? ‘

Answer

No. The only outdoor lighting control exception that aligns with the outdoor power exceptions is Exception 2 to §130.2(c)3. This means that if the lighting in question is exempt from the power limitations, it is also exempt from the motion sensing control requirements of §130.2(c)3. All other sections still apply.

K. Calculation of Allowed Lighting Power — Narrow Band Spectrum Light Source Applications

The 2022 Energy Code includes a lighting power provision for narrow band spectrum light source application to minimize the impact of electric light on local, active professional astronomy or nocturnal habitat of specific local fauna. The provision is in the format of lighting power multiplier as specified on the footnote of Table 140.7-A (footnote 3) which reads, "Footnote 3: Narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm – as mandated by local, state, or federal agencies to minimize the impact on local, active professional astronomy or nocturnal habitat of specific local fauna, shall be allowed a 2.0 lighting power allowance multiplier."

Example 6-26: Calculating Allowed Lighting Power for Narrow Band Spectrum Lighting

Question

The lighting system for a lot in Lighting Zone 2 is being designed next to an active, professional astronomical observatory. The parking lot is 800 sq. ft. with a perimeter of 280 linear feet. All lighting within 10 miles of the observatory is required by a local ordinance to use a narrow band spectrum light source with a wavelength above 580 nm to be compatible within the telescopes' ability to filter out stray light while capturing most of the wavelengths of light from the night sky. Spectral power distributions of two amber light sources are shown in the two images in Figure 6-21a.

Figure 6-21a Spectral Distribution of Light Source Product A and B

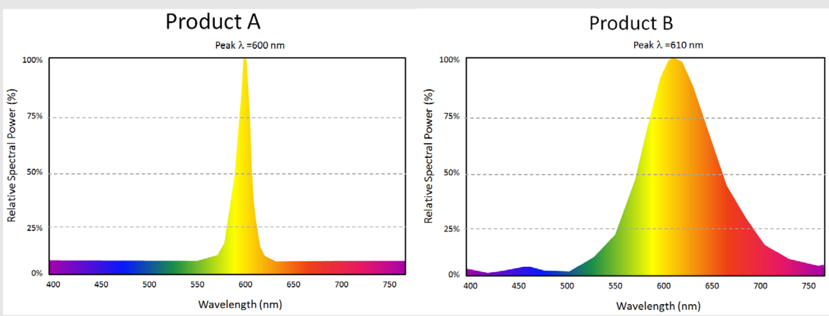


Image Source: Clanton Associates

Question 1: Which of these products meet criteria for "narrow band spectrum" light sources?

Question 2: What is the allowed lighting power for this parking lot with and without the use of a narrow band spectrum light source?

Answer

Answer 1: Narrow band spectrum light sources are those which have a spectral power distribution closely distributed around the wavelength of peak spectral power. There are no spectral power limitations on the wavelengths that are within 20 nm of the peak wavelength. As the spectrum diverges from the peak wavelength, the allowed relative spectral power declines rapidly.

Between 20 to 75nm from peak wavelength, the spectral power shall be no greater than 50% of the peak spectral power.

Beyond 75 nm the spectral power shall be no greater than 10% of the peak spectral power. This distribution is reflected in the narrow ban spectrum criteria line centered around the peak wavelength in Figure 6-21b. As shown in the figure, Product A is a narrow band spectrum light source as it fits within the spectral power criteria, whereas Product B does not comply as the spectral power exceeds the narrow band criteria.

Figure 6-21b Spectral Distribution with Narrow Band Criteria Superimposed

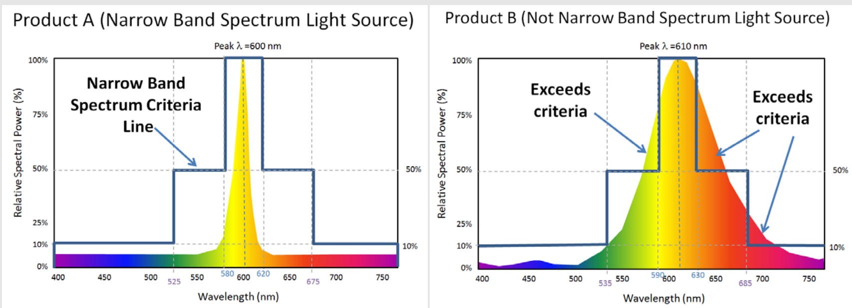


Image Source: Clanton Associates

Answer 2: To claim the two times multiplier for narrow band spectrum light sources, as described in footnote 3 to Table 140.7-A, the project must comply with all three of the following criteria:

1. The light source must have a narrow band spectrum (true for product A).

2. The dominant peak wavelength must be greater than 580 nm (true for product A with a peak wavelength of 600 nm).

3. The narrow band spectrum and dominant peak wavelength of the light source must be greater than 580 nm as mandated by local, state, federal agencies, to minimize the impact on local, active professional astronomy or on the nocturnal habitat of specific local fauna. (The credit is not available unless the ordinance specifically calls out a requirement for a narrow band spectrum.)

The allowed wattage without the narrow spectrum multiplier is calculated as follows:

Allowed Wattage = (Area Wattage Allowance) x (Area, sq. ft.) + (Linear Wattage Allowance) x (Perimeter Length, linear ft.) + (Initial Wattage Allowance)

The asphalt parking lot is 800 sq. ft. with a perimeter of 280 linear feet and is in Lighting Zone 2. From Table 140.7-A in the asphalt column of Lighting Zone 2, the power allowance factors are:

Area Wattage Allowance = 0.019 W/sq. ft., Linear Wattage Allowance = 0.15 W/lf, and Initial Wattage Allowance = 200 Watts.

Allowed Wattage = (0.019 W/sq. ft) x (800 sq. ft.) + (0.15 W/lf) x (280 lf) + (200 W) = 257.2 Watts

If the design makes use of narrow band light sources and meets all three criteria of footnote 3 to Table 140.7-A, the allowed wattage is multiplied by 2.

Narrow Band Allowed Wattage = Allowed Wattage x 2 = 257.2 W x 2 = 514.4 Watts.

Example 6-27: Low Blue Content Light Source Design

Question

A lighting system is being designed for a similar parking lot as in Example 6-23 except that it is next to a wildlife refuge and all outdoor lighting near the refuge is required by a local ordinance to use low blue content light sources to minimize the lighting impact on nocturnal animals.

If the designer specifies a narrow band spectrum light source (such as Product A in Example 6-23), can the designer make use of the narrow band spectrum lighting power allowance multiplier in determining the lighting power allowance?

Answer:

To claim the two-times multiplier for narrow band spectrum light sources, as described in footnote 3 to Table 140.7-A, the project must comply with all three of the following criteria:

1. The light source must have a narrow band spectrum.

2. The dominant peak wavelength must be greater than 580 nm.

3. The narrow band spectrum and dominant peak wavelength of the light source be greater than 580 nm, as mandated by local, state, federal agencies to minimize the impact on local, active professional astronomy or on the nocturnal habitat of specific local fauna (The credit is not available unless the ordinance specifically calls out a requirement for a narrow band spectrum.)

For this example, the narrow band spectrum credit is not available since the local ordinance called for low blue light content without specifying this had to be accomplished with narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm. As a result, the two-times multiplier for narrow band spectrum light sources cannot be used in calculating the lighting power allowance for this project.

6.5.3 Additional Light Power Allowances and Requirements by Application

The lighting power allowances for specific applications provide additional lighting power that can be layered in addition to the general hardscape lighting power allowances as applicable.

Most of a site will be classified as general hardscape and will be calculated using Table 6-4 (Table 140.7-A of the Energy Code) as the only source of allowance.

Some portions of the site may fit use categories that permit the inclusion of an additional lighting allowance for that portion of the site. These specific applications are detailed in Table 6-5 (Table 140.7-B of the Energy Code). Additional allowances for specific applications can be per application, per hardscape area, per specific application unit length, or per specific application area.

Hardscape ornamental lighting is calculated independent of the rest of the specific applications. See Section 6.5.3E for more information about the hardscape ornamental lighting allowance.

Table 6-4 (From Table 140.2-B): Additional Lighting Power Allowance for Specific Applications

Lighting Application WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Building Entrances or Exits. Allowance per door. Luminaires must be within 20 feet of the door.	Not applicable	9 watts	15 watts	19 watts	21 watts
Primary Entrances to Senior Care Facilities, Police Stations, Healthcare Facilities, Fire Stations, and Emergency Vehicle Facilities. Allowance per primary entrance(s) only. Primary entrances are entrances that provide access for the general public. This allowance is in addition to the building entrance or exit allowance above. Luminaires must be within 100 feet of the primary entrance.	Not applicable	20 watts	40 watts	57 watts	60 watts
Drive Up Windows. Allowance per customer service location. Luminaires must be within 2 mounting heights of the sill of the window.	Not applicable	16 watts	30 watts	50 watts	75 watts
Vehicle Service Station Uncovered Fuel Dispenser. Allowance per fueling dispenser. Luminaires must be within	Not applicable	55 watts	77 watts	81 watts	135 watts

Lighting Application WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
2 mounting heights of the dispenser.					
ATM Lighting. Allowance per ATM. Luminaires must be within 50 feet of the dispenser.	Not applicable	100 watts for first ATM, 35 watts for each additional ATM.	100 watts for first ATM, 35 watts for each additional ATM	100 watts for first ATM, 35 watts for each additional ATM	100 watts for first ATM, 35 watts for each additional ATM
Lighting Application WATTAGE ALLOWANCE PER UNIT LENGTH (w/linear ft.). May be used for one or two frontage side(s) per site.	**Lighting Zone 0**	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
Outdoor Sales Frontage. Allowance for frontage immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires must be located between the principal viewing location and the frontage outdoor sales area.	Not applicable	No Allowance	11 W/linear ft.	19 W/linear ft.	25 W/linear ft.
Lighting Application WATTAGE ALLOWANCE PER HARDSCAPE AREA (W/sq. ft.). May be used for any illuminated hardscape area on the site	**Lighting Zone 0**	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**

Lighting Application WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Hardscape Ornamental Lighting. Allowance for the total site illuminated hardscape area. Luminaires must be rated for 50 watts or less and be post-top luminaires, lanterns, pendant luminaires, or chandeliers.	Not applicable	No Allowance	0.007 W/ ft^2.	0.013 W/ ft^2	0.019 W/ ft^2
Lighting Application WATTAGE ALLOWANCE PER SPECIFIC AREA (W/sq. ft.). May be used as appropriate provided that only one is used for a given area (i.e., provided that two allowances are not applied to the same area).	**Lighting Zone 0**	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
Building Facades. Only areas of building façade that are illuminated qualify for this allowance. Luminaires must be aimed at the façade and capable of illuminating it without obstruction or interference by permanent building features or other objects.	Not applicable	No Allowance	0.100 W/ ft^2	0.170 W/ ft^2	0.225 W/ ft^2
Outdoor Sales Lots. Allowance for uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale. Driveways, parking lots or other non-sales areas are considered hardscape areas even if	Not applicable	0.060 W/ ft^2	0.210 W/ ft^2	0.280 W/ ft^2	0.485 W/ ft^2

Lighting Application WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
these areas are completely surrounded by sales lots on all sides. Luminaires must be within 5 mounting heights of the sales lot area.					
Vehicle Service Station Hardscape. Allowance for the total illuminated hardscape area less area of buildings, under canopies, off property, or obstructed by signs or structures. Luminaires must be illuminating the hardscape area and must not be within a building, below a canopy, beyond property lines, or obstructed by a sign or other structure.	Not applicable	0.006 W/ ft^2	0.068 W/ ft^2	0.138 W/ ft^2	0.200 W/ ft^2
Vehicle Service Station Canopies. Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.	Not applicable	0.220 W/ ft^2	0.430 W/ ft^2	0.580 W/ ft^2	1.010 W/ ft^2
Sales Canopies. Allowance for the total area within the drip line of the canopy. Luminaires must be located under the canopy.	Not applicable	No Allowance	0.470 W/ ft^2	0.622 W/ ft^2	0.740 W/ ft^2
Non-sales Canopies and Tunnels. Allowance for the total area within the drip line of the canopy or inside the tunnel.	Not applicable	0.057 W/ ft^2	0.137 W/ ft^2	0.270 W/ ft^2	0.370 W/ ft^2

Lighting Application WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Luminaires must be located under the canopy or tunnel.					
Guard Stations. Allowed up to 1,000 square feet per vehicle lane. Guard stations provide access to secure areas controlled by security personnel who stop and may inspect vehicles and vehicle occupants, including identification, documentations, vehicle license plates, and vehicle contents. Qualifying luminaires shall be within 2 mounting height of a vehicle lane or the guardhouse.	Not applicable	0.081 W/ ft^2	0.176 W/ ft^2	0.325 W/ ft^2	0.425 W/ ft^2
Student Pick-up/Drop-off zone. Allowance for the area of the student pick-up/drop-off, with or without canopy, for preschool through 12th grade school campuses. A student pick-up/drop off zone is a curbside, controlled traffic area on a school campus where students are picked-up and dropped off from vehicles. The allowed area shall be the smaller of the actual width or 25 feet, times the smaller of the actual length or 250 feet. Qualifying luminaires shall be within 2 mounting	Not applicable	No Allowance	0.056 W/ ft^2	0.200 W/ ft^2	No Allowance

Lighting Application WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.	**Lighting Zone 0**	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
heights of the student pick-up/drop-off zone.					
Outdoor Dining. Allowance for the total illuminated hardscape of outdoor dining. Outdoor dining areas are hardscape areas used to serve and consume food and beverages. Qualifying luminaires shall be within 2 mounting heights of the hardscape area of outdoor dining.	Not applicable	0.004 W/ ft^2	0.030 W/ ft^2	0.050 W/ ft^2	0.075 W/ ft^2
Special Security Lighting for Retail Parking and Pedestrian Hardscape. This additional allowance is for illuminated retail parking and pedestrian hardscape identified as having special security needs. This allowance shall be in addition to the building entrance or exit allowance.	Not applicable	0.004 W/ ft^2	0.005 W/ ft^2	0.010 W/ ft^2	No Allowance
Security Cameras. This additional allowance is for illuminated general hardscape area. This allowance shall apply when a security camera is installed within 2 mounting heights of the general hardscape area and mounted more than 10 feet away from a building.	Not applicable	No allowance	0.018 W ft^2	0.018 W/ ft^2	0.018 W/ ft^2

Source: California Energy Commission

Assigned lighting applications must be consistent with the actual use of the area. Outdoor lighting definitions in §100.1 must be used to determine appropriate lighting applications.

Specific applications that are based on the number of specific application instances on the site are calculated by multiplying each instance by the allowed wattage per instance.

Specific applications that are based on the length of an instance on the site are calculated by multiplying the total length of the instance by the allowance per linear foot for the application.

L. General Hardscape Power Trade-Offs

Allowed lighting power determined according to §140.7(d)1 for general hardscape lighting may be traded to specific applications in §140.7(d)2 if the hardscape area from which the lighting power is traded continues to be illuminated in accordance with §140.7(d)1A.

M. Specific Allowances Power Trade-Offs Not Allowed

Allowed lighting power for specific applications shall not be traded between specific applications, or to general hardscape lighting in §140.7(d)1. For each specific application, the allowed lighting power is the smaller of the allowed power determined for that specific application according to Table 140.7-B, or the actual installed lighting power that is used in that specific application.

N. Wattage Allowance per Application

The applications in this category are provided with additional lighting power, in watts (W) per instance, as defined in Table 6-5 (Table 140.7-B of the Energy Code). Use all that apply as appropriate. Wattage allowances per application are available for the following areas:

- Building entrances or exits.
- Primary entrances of senior care facilities, police stations, healthcare facilities, fire stations, and emergency vehicle facilities.
- Drive-up windows. See Section 6.5.4F for additional information about drive-up windows
- Vehicle service station uncovered fuel dispenser. See Section 6.5.4C for additional information about vehicle service stations.
- ATM lighting

O. Wattage Allowance for Outdoor Sales Frontage Application

The wattage allowance per linear foot is available only for outdoor sales frontage immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires qualifying for this allowance shall be located between the principal viewing location and the frontage outdoor. The outdoor sales frontage allowance is calculated by multiplying the total length of qualifying sales frontage by the outdoor sales frontage lighting allowance in Table 6-5 (Table 140.7-B of the Energy Code). See Section 6.5.4B for additional information about sales frontage.

P. Wattage Allowance per Hardscape Ornamental Lighting Application

The ornamental lighting allowance on the site is calculated by multiplying the total illuminated hardscape for the site by the hardscape ornamental lighting allowance in Table 6-5 (Table 140.7-B of the Energy Code), in watts per square foot (W/ft^2). Luminaires qualifying for this allowance shall be rated for 50 W or less as determined in accordance with §130.0(c) and shall be post-top luminaires, lanterns, pendant luminaires, or chandeliers. This additional wattage allowance may be used for any illuminated hardscape area on the site. See Section 6.5.4E for additional information about ornamental lighting.

Q. Wattage Allowance per Specific Area

Applications in this category are provided with additional lighting power per specific area, in watts per square foot (W/ sq. ft.), as defined in Table 6-5 (Table 140.7-B of the Energy Code). Wattage allowances per specific area are available for the following applications:

1. Building Facades

Only areas of building façade that are illuminated shall qualify for this allowance. Luminaires qualifying for this allowance shall be aimed at the façade and shall be capable of illuminating it without obstruction or interference by permanent building features or other objects. See Section 6.5.4A for additional information about building facades.

2. Outdoor Sales Lots

Allowance for uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale. Driveways, parking lots or other non-sales areas shall be considered hardscape areas, not outdoor sales lots, even if these areas are completely surrounded by sales lot on all sides. Luminaires qualifying for this allowance shall be within 5 mounting heights of the sales lot area. See Section 6.5.4B for more information.

3. Vehicle Service Station Hardscape

Allowance for the total illuminated hardscape area less area of buildings, under canopies, off property, or obstructed by signs or structures. Luminaires qualifying for this allowance shall be illuminating the hardscape area and shall not be within a building, below a canopy, beyond property lines, or obstructed by a sign or other structure. See Section 6.5.4C for additional information about vehicle service station hardscape.

4. Vehicle Service Station Canopies

Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy. See Section 6.5.4C for additional information about vehicle service station canopies.

5. Sales Canopies

Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy. See Section 6.5.4D for additional information about lighting under canopies.

6. Non-Sales Canopies and Tunnels

Allowance for the total area within the drip line of the canopy or inside the tunnel. Luminaires qualifying for this allowance shall be located under the canopy or tunnel. See Section 6.5.4D for additional information about lighting under canopies.

7. Guard Stations

Allowance up to 1,000 sq. ft. per vehicle lane. Guard stations provide access to secure areas controlled by security personnel who stop and may inspect vehicles and vehicle occupants, including identification, documentation, vehicle license plates, and vehicle contents. Qualifying luminaires shall be within 2 mounting heights of a vehicle lane or the guardhouse. See Section 6.5.4G for additional information about guarded facilities.

8. Student Pick-Up/Drop-Off Zone

Allowance for the area of the student pickup/drop-off zone, with or without canopy, for preschool through twelfth grade school campuses. A student pick-up/drop off zone is a curbside, controlled traffic area on a school campus where students are picked up and dropped off from vehicles. The allowed area shall be the smaller of the actual width or 25 ft., multiplied by the smaller of the actual length or 250 ft. Qualifying luminaires shall be within 2 mounting heights of the student pick-up/drop-off zone.

9. Outdoor Dining

Allowance for the total illuminated hardscape of outdoor dining. Outdoor dining areas are hardscape areas used to serve and consume food and beverages. Qualifying luminaires shall be within 2 mounting heights of the hardscape area of outdoor dining.

10. Special Security Lighting for Retail Parking and Pedestrian Hardscape

This additional allowance is for illuminated retail parking and pedestrian hardscape identified as having special security needs. This allowance shall be in addition to the building entrance or exit allowance.

11. Security Cameras

This additional allowance is for the illuminated general hardscape area. This allowance shall apply when a security camera is installed within 2 mounting heights of the general hardscape area and mounted more than 10 feet away from a building. See Section 6.5.4H for additional information about security cameras.

Figure 6-2: Example of a Security Camera That Does Not Qualify for Additional Lighting Power Allowance for Security Cameras

Image: California Energy Commission

6.5.4 Further Discussion About Additional Lighting Power Allowance for Specific Applications

R. Building Façades

Building façade is defined in §100.1 as the exterior surfaces of a building, not including horizontal roofing, signs, and surfaces not visible from any public viewing location. Only areas of building façade that are illuminated should qualify for this allowance. Luminaires qualifying for this allowance should be aimed at the façade and should be capable of illuminating it without obstruction or interference by permanent building features or other objects.

Building façades and architectural features may be illuminated by flood lights, sconces, or other lighting attached to the building. Building façade lighting is not permitted in Lighting Zone 0 and Lighting Zone 1. Façade orientations that are not illuminated and façade areas that are not illuminated because the lighting is obstructed shall not be included. General site illumination, sign lighting, and/or lighting for other specific applications can be attached to the side of a building and not be considered façade lighting. Wall packs mounted on sides of the buildings are not considered façade lighting when most of the light exiting these luminaires lands on areas other than the building façade.

Example 6-28: Calculating the Allowance for a Projected Area

Question

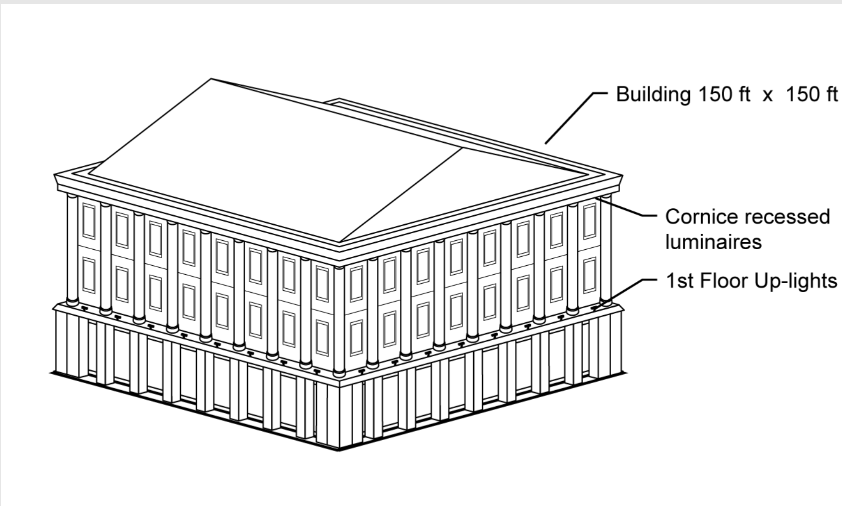


Image: California Energy Commission

A city wants to illuminate its city hall (in Lighting Zone 3) on two sides (two façades). The structure is a three-story building with a colonnade on the second and third floors and a cornice above. The columns are considered important architectural features and the principal goal of the lighting project is to highlight these features. The columns are 30 ft. tall x 3 ft. in diameter and are spaced at 8 ft. For the purposes of determining the lighting power allowance for the building, what is the surface area to be illuminated? What is the lighting power allowance? The columns will be illuminated by downlights at the cornice and uplights above the first floor.

Answer

The area of the façade for the purposes of calculating the lighting allowance is the projected area of the illuminated façade. Architectural features such as columns, recesses, facets, etc. are ignored. The illuminated area for each façade is therefore 30 ft. x 150 ft. or 4,500 sq. ft. The façade allowance for Lighting Zone 3 is 0.17 W/sq. ft., so the total power allowed is 765 W per façade, or 1,530 W total.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Facade	0.17 W/ sq. ft.	4,500 sq. ft.	765 W per facade

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
-	-	**Total Power Allowance:**	**1,530 W**

Example 6-29: Permanent vs. Temporary Façade Lighting

Question

I am designing a hotel building. Permanently mounted marquee lights will be installed along the corners of the building. The lighting will be turned on at night, but only for the holiday season, roughly between mid-November and mid-January. The lighting consists of a series of 7 W LED luminaires spaced at 12 inches on-center (OC) along all the corners of the building and along the top of the building. Essentially, the lights provide an outline of the building. Are these considered façade lighting? Because they will only be used for two months of the year, are they considered temporary lighting and therefore exempt from lighting power allowance requirements?

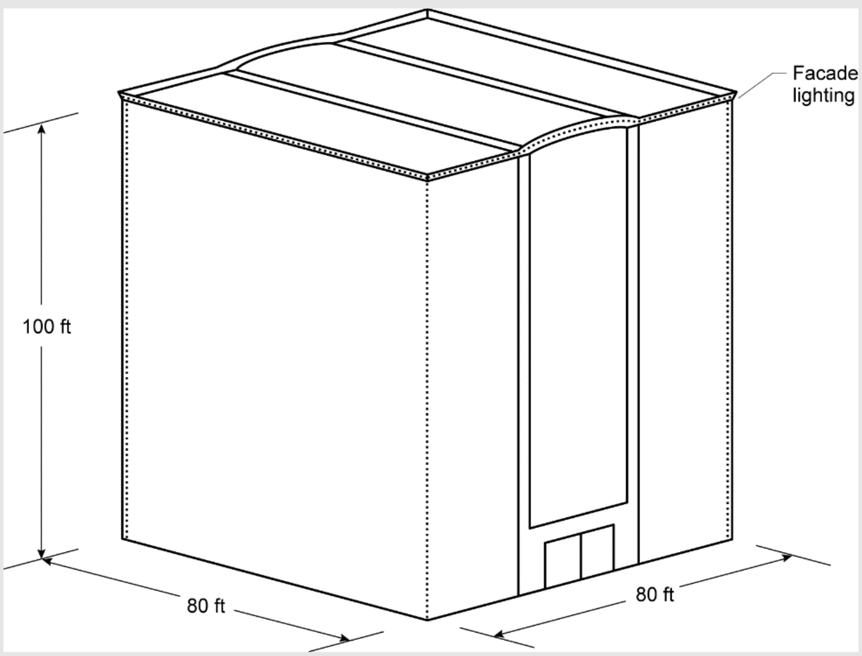


Image: California Energy Commission

Answer

The lighting is permanent lighting and must comply with the Energy Code. Temporary lighting is defined in §100.1 as a lighting installation with plug-in connections that does not persist beyond 60 consecutive days or more than 120 days per year. Anything that is permanently mounted to the building is considered permanent lighting, and the hours of intended use do not affect its status as permanent lighting. Because this lighting is primarily used to accent the architectural outline of the building, it may be considered façade lighting. And because all corners of the building are illuminated, all four facades may be illuminated. The area on each façade is 80 ft. x 100 ft. or 8,000 sq. ft. The total illuminated area is four times 8,000 sq. ft. or 32,000 sq. ft. The Lighting Zone 3 allowance for façade lighting is 0.17 W/sq. ft., and the specific application power allowance for façade lighting is 5,440 W.

There are 100 ft. x 4 plus 80 ft. x 4 luminaires (a total of 720 luminaires) on the building. Each luminaire is 7 W. The installed power is 720 luminaires times 7 W/luminaire or 5,040 W. The installed power is less than the specific application power allowance, so the façade lighting complies. If this building were in Lighting Zone 2, the specific application power allowance would be 0.1 W/sq. ft. or a total of 3,200 W. The lighting design would not comply in Lighting Zone 2.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Facade	0.17 W/ sq. ft.	32,000 sq. ft.	5,440 W
-	-	**Total Power Allowance:**	**5,440 W**

Example 6-30: Power Allowance for Façades

Question

Portions of the front façade of a proposed wholesale store in Lighting Zone 3 are going to be illuminated. The front wall dimensions are 120 ft. by 20 ft. There is 250 sq. ft. of fenestration in the front wall that is illuminated by the façade lighting. Signs cover another 500 sq. ft. of the front wall, and another 400 sq. ft. is not illuminated at all. What is the allowed front façade lighting power?

Answer

The gross wall area is 2,400 sq. ft. (120 x 20). However, we must subtract all those areas that are not illuminated. Note that because the 250 sq. ft. of fenestration is intended to be illuminated by the façade lighting, this area may be included in the total area eligible for power calculations.

The areas not eligible for power calculations include:

500 sq. ft. of signs + 400 sq. ft. of unlighted façade = 900 sq. ft.

The net wall area used for façade lighting: 2,400 sq. ft. - 900 sq. ft. = 1,500 sq. ft.

From Table 6-5 (Table 1407-B of the Energy Code), the allowed façade lighting power density in Lighting Zone 3 is 0.17 W/ sq. ft.

The allowed façade lighting power based on the net wall area is 1,500 sq. ft. x 0.17 W/ sq. ft. = 255 W.

The allowed power is therefore the smaller of actual wattage used for façade lighting or 255 W.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Facade	0.17 W/ sq. ft.	1,500 sq. ft.	255 W
-	-	**Total Power Allowance:**	**255 W**

Example 6-31: Sign Lighting

Question

Is sign lighting part of my façade lighting?

Answer

The sign area must be subtracted from the façade area so that the area is not double-counted. The sign lighting must meet the requirements of the Energy Code for sign lighting. See Chapter 7 for more information about sign lighting.

Example 6-32: Hardscape vs. Façade Lighting

Question

If I mount a luminaire on the side of my building to illuminate an area, is it considered façade lighting or hardscape lighting?

Answer

It depends on the primary intent of the luminaire. For example, if the luminaire is primarily illuminating the walls (such as a sconce), then it should be considered part of the building façade lighting. If, on the other hand, the luminaire is primarily illuminating the parking lot beyond (most wall packs), then it should be part of the hardscape lighting. It should be noted that lighting power tradeoffs are not allowed between building façade and hardscape areas.

S. Sales Frontage

This additional allowance is intended to accommodate the retailers' need to highlight merchandise to motorists who drive by their lot. Outdoor sales frontage includes car lots but can also include any sales activity.

Outdoor sales frontage must be immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires qualifying for this allowance shall be located between the principal viewing location and the frontage outdoor. The outdoor sales frontage allowance is calculated by multiplying the total length of qualifying sales frontage by the outdoor sales frontage lighting allowance in Table 147-B of the Energy Code.

When a sales lot qualifies for the sales frontage allowance, the total sales lot wattage allowance is determined by adding the following three layers:

- General hardscape lighting power allowance
- Outdoor sales frontage
- Outdoor sales lot

T. Vehicle Service Stations

According to the definition in §100.1, a vehicle service station is a gasoline, natural gas, diesel, or other fuel-dispensing station. In addition to allowances for building entrances and exits, hardscape ornamental lighting, building façade, and outdoor dining allowances, as appropriate, the total wattage allowance specifically applying to vehicle service station hardscape is determined by adding the following layers, as appropriate:

- General hardscape lighting power allowance
- Vehicle service station uncovered fuel dispenser (allowance per fueling dispenser, with 2 mounting heights of dispenser)
- Vehicle service station hardscape (less area of buildings, under canopies, off property, or obstructed by signs or other structures)
- Vehicle service station canopies (within the drip line of the canopy)

The lighting power allowances are listed in Table 140.7-B of the Energy Code.

Example 6-33: Canopy Area and Hardscape Area

Question

Where does canopy area end and hardscape area start?

Answer

The horizontal projected area of the canopy on the ground establishes the area for under-canopy lighting power calculations. This area also referred to as the "drip line" of the canopy.

U. Under Canopies

According to the definition in §100.1, a "canopy" is a permanent structure, other than a parking garage, consisting of a roof and supporting building elements, with the area beneath at least partially open to the elements. A canopy may be freestanding or attached to surrounding structures. A canopy roof may serve as the floor of a structure above.

The definition of a canopy states that a canopy is not a parking garage. A parking garage is classified as an unconditioned interior space, whereas a canopy is classified as an outdoor space.

The lighting power allowance for a canopy depends on its purpose. Service station canopies are treated separately. (See the previous section.) The two types of canopies addressed in this section are those that are used for sales and those that are not. Non-sales canopies include covered walkways and covered entrances to hotels, office buildings, convention centers and other buildings. Sales canopies specifically cover and protect an outdoor sales area, including garden centers, covered automobile sales lots, and outdoor markets with permanent roofs. The lighting power allowances are listed in Table 140.7-B of the Energy Code.

The area of a canopy is defined as the "horizontal projected area," in plan view, directly underneath the canopy. This area is also referred to as the "drip line" of the canopy. Canopy lighting, either sales or non-sales, shall comply separately; for example, trade-offs are not permitted between other specific lighting applications or with general site illumination.

General site lighting or other specific applications lighting and/or sign lighting that is attached to the sides or top of a canopy cannot be considered canopy lighting. For example, internally illuminated translucent panels on the perimeter of a canopy are considered sign lighting, while the lighting underneath the canopy and directed toward the ground is canopy lighting.

Example 6-34: Power Allowance Under Canopies

Question

The first floor of an office tower in Lighting Zone 3 is setback 20 ft. on the street side. The width of the recessed façade is 150 ft. The primary purpose of the setback (and canopy) is to provide a suitable entrance to the office tower; however, space under the canopy is leased as newsstand, a flower cart, and a shoeshine stand. These commercial activities occupy about half of the space beneath the canopy. What is the allowed lighting power?

Answer

The total canopy area is 20 ft. x 150 ft. or 3,000 sq. ft. The general hardscape allowance for the site will need to be separately determined. The canopy allowance is an additional layer allowed only for the canopy area. The 1,500 sq. ft. used for the flower cart, newsstand, and shoeshine stand is considered a sales canopy, and the allowance is 0.622 W/ sq. ft. or a total of 933 W. The other 1,500 sq. ft. is a non-sales canopy, and the allowance is 0.270 W/sq. ft. or a total of 405 W. Trade-offs are not permitted between the sales portion and the non-sales portions.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Non-Sales Canopy	0.270W/ sq. ft.	1,500 sq. ft.	405 W
Sales Canopy	0.622 w/ sq. ft.	1,500 sq. ft.	933 W
-	-	**Total Power Allowance:**	**1,338 W**

V. Ornamental Lighting

"Ornamental lighting" is defined in §100.1 as post-top luminaires, lanterns, pendant luminaires, chandeliers, and marquee lighting. However, marquee lighting does not qualify for the ornamental lighting allowance. The allowances for ornamental lighting are listed in Table 140.7-B of the Energy Code.

The ornamental lighting allowance on the site is calculated by multiplying the total illuminated hardscape for the site by the hardscape ornamental lighting allowance in Table 140.7-B. This allowance is calculated separately and is not accumulated into the other allowances. This additional wattage allowance may be used for any illuminated hardscape area on the site.

Luminaires used for ornamental lighting as defined in Table 140.7-B shall have a rated wattage, as listed on a permanent, preprinted, factory-installed label, of 50 W or less.

Example 6-35: Bollard Luminaires

Question

Are bollard luminaires considered ornamental lighting?

Answer

No, Ornamental lighting is defined in Table 140.7-B of the Energy Code as post-top luminaires, lanterns, pendant luminaires, chandeliers.

W. Drive-Up Windows

Drive-up windows are common for fast food restaurants, banks, and parking lot entrances. To qualify, a drive-up window must have someone working behind the "window." Automatic ticket dispensers at parking lots do not count.

The lighting power allowances are listed in Table 140.7-B of the Energy Code as a wattage allowance per application.

The wattage allowance in Lighting Zone 3 is 125 W for each drive-up window.

Luminaires qualifying for this allowance must be within 2 mounting heights of the sill of the window.

Example 6-36: Power Allowance for Drive-Up Window

Question

A drive-up window in Lighting Zone 2 has width of 7 ft. What is the allowed lighting power for this drive-up window?

Answer

The width of a drive-up window in not used for determining the allowed wattage. In Lighting Zone 2, 30 W is allowed for each drive-up window.

X. Guard Stations

Guard stations include the entrance driveway, gatehouse, and guardhouse that provide access to secure areas controlled by security personnel who stop and may inspect vehicles and vehicle occupants, including identification documentation, vehicle license plates, and vehicle contents.

There is an allowance of up to 1,000 sq. ft. per vehicle lane. Qualifying luminaires shall be within 2 mounting heights of a vehicle lane or the guardhouse.

The power allowances for guarded facilities are listed in Table 140.7-B of the Energy Code.

Example 6-37: Specific Application Power Allowance for Guard Stations

Question

A guard station to the research campus of a defense contractor consists of a guard station building of 300 sq. ft. Vehicles enter to the right of the station and exit to the left. What is the outdoor lighting power allowance? The guard station is located in Lighting Zone 2.

Answer

Since there are two vehicle lanes, the specific application allowance for a guard station located in Lighting Zone 2 is 2 lanes x 300 sq. ft. x 0.176 W/sq. ft. or 105.6 W.

Y. Security Cameras

Security cameras for general hardscape areas apply to nonbuilding-mounted security cameras that require higher levels of general illumination to identify objects or determine what activities are occurring in a space.

This allowance applies for any general hardscape areas where a security camera is installed within two camera mounting heights of the general hardscape area. The camera must be mounted at least 10 feet away from an adjacent building to qualify for this allowance. This allowance can be applied to the entire general hardscape area associated with the camera's field of view.

The power allowances for security cameras are listed in Table 140.7-B of the Energy Code.

Example 6-38: Power Allowance for Security Cameras

Question

My building has two parking lots located on either side of the building. The parking lot on the east is 180 ft. long and 130 ft. wide and has two security cameras mounted on the building. The parking lot to the west is 180 ft. long and 250 ft. wide and has security cameras mounted on the light poles. This building is in Lighting Zone 2. What is the outdoor lighting power allowance I can use?

Answer

Since the parking lots are located on separate sides of the building, the power allowances must be calculated separately for each parking lot. The security camera allowance applies only to the parking lot on the west side of the building, since these cameras are mounted on poles more than 10 feet away from the building (see Example 6-36).

First the general hardscape allowance for both parking lots in Lighting Zone 2 must be calculated.

The east parking lot general hardscape area is 180 ft. x 130 ft., or 23,400 sq. ft. The area wattage allowed is 23,400 sq. ft. x 0.019 W/sq. ft. or 444.6 W.

The perimeter of this hardscape is the sum of the sides 180 ft. + 130 ft. + 180 ft. + 130 ft. or 620 ft. The linear wattage allowed is 620 ft. x 0.15 W/sq. ft. or 93 W.

The initial wattage allowance will be split between the east and the west parking lots. Half the initial wattage allowance is equal to 100 W.

The general hardscape allowance for the east parking lot is 637.6 W (444.6 W+ 93 W + 100 W).

Similarly, the west parking lot general hardscape area is 180 ft. x 205 ft., or 36,900 sq. ft. The area wattage allowed is 36,900 sq. ft. x 0.019 W/sq. ft. or 701.1 W.

The perimeter of this hardscape is the sum of the sides 180 ft. + 205 ft. + 180 ft. + 205 ft. or 770 ft. The linear wattage allowed is 770 ft. x 0.15 W/sq. ft. or 115.5 W.

The initial wattage allowance will be split between the east and the west parking lots. Half the initial wattage allowance is equal to 100 W.

The general hardscape allowance for the west parking lot is 916.6 W (701.1 W + 115.5 W + 100 W).

The security camera allowance can then be applied to the west parking lot general hardscape allowance. The west parking lot general hardscape area is 180 ft. x 250 ft. or 36,900 sq. ft. The west parking lot security camera allowance is 36,900 sq. ft. x 0.018 W/sq. ft. or 664.2 W.

The total wattage allowance for the west parking lot is 916.6 W + 664.2 W or 1580.8 W.

The calculation for the west parking lot can be tabulated as below.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Initial, Gen. Hardscape	100 W	-	100 W
Area, Gen. Hardscape	0.019 W/sq. ft	36,900 sq. ft.	701.1 W
Perimeter, Gen. Hardscape	0.15 W/LF	770 ft.	115.5 W
Security Camera	0.018 w/ sq. ft.	36,900 sq. ft.	664.2 W
	-	**Total Power Allowance:**	**1,580.8 W**

Example 6-39: Application of Security Cameras

Question

My building has a security camera mounted to a building above a side entry door facing the loading dock. Can I apply the security camera allowance to the loading dock general hardscape area?

Answer

No, the security camera allowance does not apply to the outdoor lighting system of the building as these are building-mounted security cameras. The security camera allowance applies only to security cameras that are installed within 2 mounting heights of the general hardscape area and mounted more than 10 feet away from buildings.

Alterations and Additions for Outdoor Lighting

§141.0(b)2L

The Energy Code applies to alterations and additions to outdoor lighting systems, and the application of the Energy Code to alterations depends on the scope of the proposed improvements.

"Outdoor lighting alterations" generally refer to replacing entire luminaires or adding luminaires to an existing outdoor lighting system. Modifications or retrofitting existing luminaires (for example changing the luminaire light source) is not considered outdoor lighting alterations unless the modification increases the connected lighting load.

Example 6-40: Requirements for Replacing Ballasts

Question

I am going to change the ballasts in my façade lighting system. Will I be required to meet the outdoor lighting alteration requirements?

Answer

No, the replacement of only lamps or ballasts in outdoor lighting systems is not considered an alteration and does not trigger compliance with outdoor lighting requirements. Replacing entire luminaires will trigger mandatory lighting control requirements for the altered (replaced) luminaires only. Replacing 50 percent or more of the existing luminaires or increasing the connected lighting load for any outdoor lighting application will trigger the prescriptive lighting power allowance requirements of the Energy Code.

6.6.1 Outdoor Lighting Alterations – Increasing Connected Lighting Loads

For alterations that increase the connected lighting load in a lighting application listed in Table 140.7-A or 140.7-B, the added or altered luminaires must meet all the applicable requirements of §130.2(c) and §140.7.

Example 6-41: Requirements for Adding New Luminaires in a Parking Lot

Question

We are adding new luminaires to the existing lighting systems in a parking lot. Which code requirements are triggered by this alteration?

Answer

Because additional load is being added to the parking lot general hardscape lighting, the entire general hardscape area must comply with the lighting power allowance requirements. However, only the newly installed lighting system must comply with the applicable mandatory requirements, including control requirements and luminaire shielding requirements.

6.6.2 Outdoor Lighting Alterations – 10 Percent or More of Existing Luminaires Are Replaced

For alterations in parking lots or outdoor sales lots that do not increase connected lighting load, where 10 percent or more of the existing luminaires are replaced, and where the luminaire is mounted 24 feet or less above the ground, the replaced luminaires must meet the applicable controls requirements of §130.2(c)1 and §130.2(c)3.

For parking lots and outdoor sales lots where the bottom of the luminaire is mounted greater than 24 feet above the ground and for all other lighting applications, the replaced luminaires must meet the applicable controls requirements of §130.2(c)1 and either comply with §130.2(c)2 or be controlled by lighting control systems (including motion sensors) that reduce lighting power by at least 40 percent when the area is vacated.

If fewer than five existing luminaires are replaced, the replacement luminaires are exempt from the control requirements for alterations to existing outdoor lighting systems.

Example 6-42: BUG Requirements for Lighting Alterations

Question

We are replacing 20 percent of the existing HID luminaires in a parking lot. Does the luminaire shielding requirement apply to the new and existing luminaires?

Answer

Replacement luminaires must meet the luminaire shielding (BUG) requirements if the luminaire initial lumen output is 6,200 lumens or greater; however, existing luminaires that are not replaced are not required to be upgraded to meet the luminaire BUG requirement.

Section 141.0(b)2L specifies that all altered luminaires must meet applicable mandatory requirements, including the BUG requirements for replacements luminaires. Therefore, replacement luminaires that are greater than 6,200 initial luminaire lumens must meet the luminaire BUG requirements, even if fewer than five luminaires or 10 percent of the luminaires on site are replaced.

6.6.3 Outdoor Lighting Alterations – Half (50 Percent) or More of Existing Luminaires Are Replaced

For alterations that do not increase connected lighting load, where 50 percent or more of the existing luminaires are replaced in a lighting application listed in Table 140.7-A or 140.7-B, the replaced luminaires must meet the control requirements discussed in the previous section and meet the lighting power allowance requirements of §140.7.

If the replacement luminaires are at least 40 percent more efficient in lighting power than the existing luminaires, the alteration is exempt from the lighting power allowance requirements of §140.7.

If fewer than five existing luminaires are replaced, the replacement luminaires are exempt from the control requirements and lighting power allowance requirements.

Example 6-43: Requirements for Replacing More Than 50 Percent of Luminaires

Question

In a service station, we are replacing five under-canopy luminaires, which is more than 50 percent of the existing under canopy luminaires. Does this trigger the alteration requirements for outdoor lighting? Do we need to bring non-canopy lighting such as hardscape lighting up to code as well?

Answer

Yes, §141.0(b)2Liii specifies that when five or more luminaires are replaced, or 50 percent or more of luminaires are replaced in a given lighting application included in Energy Code Tables 140.7-A and 140.7-B, the alteration requirements apply. So, in this example, all under-canopy luminaires must meet the lighting power allowance requirements of §140.7 and the applicable control requirements of §130.2. Existing outdoor lighting systems for hardscape and other outdoor lighting applications do not need to meet alteration requirements even if they are included in the permit along with the canopy lighting.

Example 6-44: Exemption From Lighting Power Allowance Requirements

Question

Fifty HID exterior pole luminaires in a parking lot are being replaced with 50 new LED luminaires. However, to improve poor coverage in one end of the lot, an additional three pole luminaires are added, bringing the total new luminaire count to 53. Despite the addition of 3 luminaires, the total connected load for the 53 luminaires were reduced by 42 percent compared to the original 50 luminaires. Does this project have to meet the outdoor lighting power allowance requirements in §140.7?

Answer

No, the project does not have to meet the lighting power allowance requirements in §140.7. Even though the number of luminaires has increased, the total wattage of the project is less than before, so the connected lighting load has decreased. Since the connected load was reduced by 40 percent or more compared to the original luminaires, the exception to §141.0(b)2Liii applies, and the new fixtures are not required to comply with the lighting power allowance requirements in §140.7.

6.6.4 Outdoor Lighting Alterations – Less Than 10 Percent of Existing Luminaires Are Replaced

For alterations that do not increase connected lighting load and replace fewer than five luminaires or fewer than 10 percent of the existing luminaires, the replacement luminaires must comply with the luminaire shielding (BUG) requirements of §130.2(b) and applicable installation and acceptance requirements of §130.4.

Example 6-45: Outdoor Lighting Alteration Triggers

Question

I am retrofitting all my existing HID parking lot lights with an LED retrofit kit. What requirements do I need to follow for the LED retrofits?

Answer

Outdoor lighting alteration requirements apply when increasing the connected lighting load or when replacing existing luminaires. Modifications and retrofitting of existing luminaires are not an outdoor lighting alteration if the modification or retrofit does not increase the connected lighting load.

If the LED retrofit increases the connected lighting load, retrofit luminaires must meet all the applicable requirements of §130.2(c) and §140.7.

6.6.5 Outdoor Lighting Additions — Mandatory Control Requirements and Lighting Power Requirements

§141.0(a)1., §130.0, §130.2

Outdoor lighting additions include adding illuminated area to an existing outdoor lighting site. The additional illuminated area must comply with all mandatory lighting control requirements and lighting power allowance requirements in §§110.9, 130.0, 130.2, 130.4, and 140.7.

A. Mandatory Requirements

Additions to existing outdoor lighting must meet all mandatory measures for the newly installed lighting system. The mandatory requirements include:

- Lighting control device and system functionality requirements in §110.9 (Refer to section 6.4.3 for more information).
- Luminaire shielding requirements, also known as backlight, uplight, and glare (BUG) requirements in §130.2(b) (Refer to Section 6.4.1 for more information).
- Outdoor lighting control requirements in §130.2(c) (Refer to Section 6.4.2 for more information).
- Outdoor lighting control acceptance testing in §130.4 (Refer to Sections 6.4.2 and 6.7.5 for more information).

B. Lighting Power Allowance Requirements

Outdoor lighting additions must also comply with lighting power allowance requirements in §140.7. (Refer to Section 6.5 for more information.)

6.6.6 Outdoor Lighting Additions and Alterations — More Examples

Example 6-46: Power Allowance for Additional Outdoor Dining (Inside Illuminated Area)

Question

A strip mall in Lighting Zone 3 with a common parking lot has its lighting system already designed and installed. A restaurant moves into one of the buildings and designates 400 sq. ft. as outdoor dining. The outdoor dining area is within the illuminated area (5 mounting heights) of the preexisting lighting. How is the allowable lighting calculated?

Answer

The allowable lighting power can be calculated in two ways:

Compliance Method 1

Calculate only the additional allowance layer for the outdoor dining area for specific applications (Outdoor Dining) as contained in Table 140.7-B of the Energy Code. In this case, the allowance is 0.050 W/sq. ft. Multiplying this allowance by 400 sq. ft. yields 20 W.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Outdoor Dining	0.050 W/ sq. ft.	400 sq. ft.	20 W
Left intentionally blank-	**Left intentionally blank**	**TOTAL POWER ALLOWANCE**	**20 W**

Compliance Method 2

One could have the permit cover all the site lighting including the outdoor dining area. (This second compliance path would provide a greater power allowance but would require more work in the application process.) This yields a higher allowance only if the current lighting system serving hardscape areas for the rest of the site has less wattage than the calculated total site hardscape wattage allowance. Additional allowances would be possible if one upgraded to the current hardscape system for other parts of the site and reduced its wattage.

Example 6-47: Power Allowance for Additional Outdoor Dining (Outside Illuminated Area)

Question

A strip mall in Lighting Zone 3 with a common asphalt parking lot has the parking lot lighting system designed and installed. A restaurant moves into one of the buildings and designates 400 ft.^{2} as outdoor dining. The outdoor dining area is outside the illuminated area of the preexisting parking lot lighting. How is the allowable lighting calculated?

Answer

In addition to adding outdoor dining area, which is a specific application that is allowed more lighting, the illuminated general hardscape lighting area is also increasing in size by 400 sq. ft. Adding illuminated hardscape area results in increased general hardscape area wattage allowances (AWA) and increased linear wattage allowances (LWA), but it does NOT add an additional initial wattage allowance (IWA) because only one initial wattage allowance is allowed per site. The allowable lighting power can be calculated in two ways:

Compliance Method 1

Calculate the general hardscape area wattage allowances (AWA) and the increase to the general hardscape linear wattage allowances (LWA) and the additional allowance layer for the outdoor dining area for specific applications (Outdoor Dining) as contained in Table 140.7-B of the Energy Code. As discussed, previously, it is not permissible to also claim the general hardscape initial wattage allowance (IWA) as this is calculated only once per site. The linear wattage allowance applies only to the new perimeter length, which is not adjacent to the previously illuminated area that is part of the site.

As shown in the figure below, the perimeter length is 41 ft. (25 ft. + 16 ft.). In LZ3, the AWA is 0.021 W/sq. ft. and the LWA is 0.20 W/ft. The additional allowance for the outdoor dining area for specific applications (Outdoor Dining) as contained in Table 140.7-B is 0.05 W/sq. ft. Thus, for a perimeter length of 41 ft. and an area of 400 sq. ft., the total lighting wattage allowance is:

Hardscape LWA of 0.20 W/ sq. ft. x 41 ft. = 8.2 W

Hardscape AWA of 0.021 W/sq. ft. x 400 sq. ft. = 8.4 W

Specific Allowance Outdoor Dining 0.05 W/sq. ft. x 400 sq. ft. = 20 W

Total allowance = 36.6 W

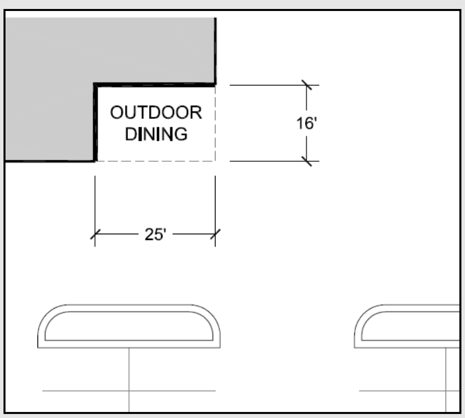


Image: California Energy Commission

Compliance Method 2

One could have the permit cover all the site lighting including the outdoor dining area. (This second compliance path would provide a greater power allowance but would require more work in the application process.) This yields a higher allowance only if the current lighting system serving hardscape areas for the rest of the site has less wattage than the calculated total site hardscape wattage allowance.

Outdoor Lighting Compliance Documents and Acceptance Tests

This section contains information about the certificate of compliance, certificate of installation, and certificate of acceptance needed for compliance with the nonresidential outdoor lighting requirements of the Energy Code.

6.7.1 Overview

At the time a building permit application is submitted to the local enforcement agency, the applicant also submits plans and energy compliance documentation, including the certificate of compliance. The enforcement agency plan checkers examine these documents for compliance with the Energy Code

The person responsible for the construction of the lighting system should submit the certificate of installation and certificate of acceptance to the local building department or the local enforcement agency after the installation and before receiving the building occupancy permit.

6.7.2 Compliance Documentation and Numbering Scheme

The Energy Code use the following numbering scheme for the nonresidential lighting compliance documents:

NRCC	Nonresidential Certificate of Compliance
NRCI	Nonresidential Certificate of Installation
NRCA	Nonresidential Certificate of Acceptance
LTI	Lighting, Indoor
LTO	Lighting, Outdoor
LTS	Lighting, Sign
01	The first set of compliance documents in this sequence
E	Primarily used by enforcement authority
A	Primarily used by acceptance tester

The paper prescriptive compliance documents have a limited number of rows per section for entering data. Some designs may need fewer rows, and some designs may need additional rows. If additional rows are required for a particular design, then multiple copies of that page may be used.

6.7.3 Certificate of Compliance Documents

The certificate of compliance is used to demonstrate that the overall design of the regulated building or system complies with the Energy Code requirements.

The plans examiner will be responsible for verifying that these documents are submitted with the building plans and are complete when required. See Section 2.2.2 for more information about the certificate of compliance.

The nonresidential outdoor lighting certificate of compliance includes the following:

- NRCC-LTO-E: Certificate of Compliance, Outdoor Lighting

6.7.4 Certificate of Installation Documents

The certificate of installation is used primarily to declare that what was installed matches the plans and certificates of compliance. The certificate of installation is signed by a person with an approved license.

Even if the design has errors and has specified incorrect features and devices, the installer is responsible to meet all the applicable requirements that he or she installs.

A copy of the completed signed and dated installation certificate must be posted at the building site for review by the local enforcement agency in conjunction with requests for final inspection for the building. See Section 2.2.5 for more information about installation certificates.

Before a lighting control system, including an energy management control system (EMCS), can be recognized for compliance with the lighting control requirements in the Energy Code, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit an Installation Certificate (§130.4[b] 1 and 2).

For sign lighting controlled by a lighting control system or by an EMCS, the NRCI-LTO-02-E must be completed

The nonresidential outdoor lighting certificate of installation includes the following:

- NRCI-LTO-01-E: Certificate of Installation, Outdoor Lighting
- NRCI-LTO-02-E: Certificate of Installation, Energy Management Control

6.7.5 Certificate of Acceptance

Before an occupancy permit is granted for a newly constructed building or space, or a new lighting system serving a building, space, or site is operated for normal use, all outdoor lighting controls serving the site shall be certified as meeting the acceptance requirements for code compliance. A certificate of acceptance shall be submitted to the local enforcement agency under Administrative Regulations §10-103(a).

The acceptance requirements that apply to outdoor lighting controls include:

- Certifying plans, specifications, installation certificates, and operating and maintenance information to meet the requirements of the Energy Code.
- Certifying that outdoor lighting controls meet the applicable requirements of §110.9 and §130.2.

Lighting controls acceptance testing must be performed by a certified acceptance test technician, and a certificate of acceptance must be completed and submitted before the local enforcement agency can issue the certificate of occupancy. See the following Chapter 2 and Chapter 13 for additional information on compliance and enforcement, and acceptance requirements.

The nonresidential outdoor lighting certificate of acceptance includes the following:

- NRCA-LTO-02-A: Certificate of Acceptance, Outdoor Lighting Controls

6.7.6 Acceptance Testing

The primary purpose of outdoor lighting acceptance tests is to assure the lighting controls are configured properly and are functioning as expected in meeting the energy code requirements.

The procedures for performing the lighting controls acceptance tests are documented in Reference Nonresidential Appendix NA7. See the following sections for the outdoor lighting controls acceptance testing procedures:

- NA7.8.1 for Motion Sensing Controls
- NA7.8.2 for Photocontrols
- NA7.8.5 for Automatic Scheduling Controls

See Section 2.2.7 for more information about the certificate of compliance.

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7. Sign Lighting

7.1 Overview

This chapter discusses the requirements for sign lighting in the Building Energy Efficiency Standards (Energy Code). There are requirements for controls, maximum allowable power, and minimum efficacy. These requirements conserve energy, reduce peak electric demand, and are both technically feasible and cost-effective.

The Energy Code does not allow trade-offs between sign lighting power allowances and other end uses.

7.1.1 Scope and Application

The sign lighting requirements address both indoor and outdoor illuminated signs, including signs with unfiltered light-emitting diodes (LEDs) and unfiltered neon. The Energy Code includes control requirements for all illuminated signs (§130.3) and lighting power requirements for internally and externally illuminated signs (§140.8).

The sign lighting requirements are the same for conditioned and unconditioned spaces, and they apply to lighting specifically used to illuminate a sign. Lighting that is not used to illuminate a sign must meet the requirements for indoor or outdoor lighting.

7.1.2 Summary of Requirements

§110.9, §130.0, §130.3, §140.8 and §141.0

A. Mandatory Measures

The Energy Code requires that indoor and outdoor sign lighting be automatically controlled.

The mandatory sign lighting control requirements include:

- Automatic shutoff controls.
- Dimming controls.
- Demand responsive controls for electronic message centers.

All lighting control devices and systems must meet the functionality requirements of §110.9 as applicable. More details on mandatory controls are provided in Section 7.3 of this chapter.

B. Sign Lighting Power

Sign lighting power requirements apply to both indoor and outdoor signs and contain two prescriptive compliance options:

1. The watts per square foot approach specifies a maximum lighting power that can be installed, expressed in W/ft² of illuminated sign area.

2. The alternate light source approach specifies efficient lighting sources (and requirements for electronic ballasts, high-efficacy lamps, efficient power supplies, and efficient transformers) that comply.

More details on the sign lighting power requirements are provided in Section 7.4 of this chapter.

7.2 Mandatory Measures

Mandatory requirements for sign lighting are specified in §110.9, §110.12, §130.0, and §130.3. The mandatory requirements include control device, control installation, and system functionality requirements. Mandatory features also set requirements for how lighting systems are classified according to technology, and how to calculate installed wattage.

7.2.1 Lighting Control Functionality

All installed lighting control devices and systems must meet the functionality requirements in §110.9(b). In addition, all components of a lighting control system installed together shall meet all applicable requirements for the application for which they are installed as required in §130.0 through §130.5, §140.6 through §140.8, §141.0, and §150.0(k).

The person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices must sign and submit an installation certificate before a lighting control system, including an energy management control system (EMCS), can be recognized for compliance with the lighting control requirements in the Energy Code (§130.4[b] 1 and 2).

Designers and installers should review features of their specified lighting control products for compliance with §110.9(b) as part of the code compliance process.

A. Automatic Time-Switch Controls

Time-switch lighting control products must provide the functionality listed in §110.9(b)1.

B. Daylighting Controls

Daylighting control products must provide the functionality listed in §110.9(b)2.

C. Dimmers

Dimmer products must provide the functionality listed in §110.9(b)3.

D. Occupant-Sensing Controls

Occupant-sensing control products must provide the functionality listed in §110.9(b)4 and §110.9(b)6, and must automatically reduce lighting or turn the lighting off within 20 minutes after the area has been vacated.

7.2.2 Determining Luminaire Power

§130.0(c)

Luminaire power must be determined in accordance with the applicable provisions of §130.0(c). Note that the installed wattage of sign lighting is not considered when using the Alternate Lighting Source compliance option in §140.8(b). See Section 7.4 of this chapter for more information about sign lighting energy requirements.

These are the requirements for determining luminaire power:

1. The wattage of luminaires with line voltage lamp holders not served by drivers, ballasts, or transformers shall be the maximum rated wattage or relamping-rated wattage of the luminaire as labeled in accordance with §130.0(c)1.
2. The wattage of luminaires with permanently installed or remotely installed ballasts shall be the operating input wattage of the rated lamp/ballast combination published in the ballast manufacturer’s catalog based on independent testing lab reports as specified by UL 1598.
3. The wattage of luminaires and lighting systems with permanently installed or remotely installed transformers shall be the rated wattage of the lamp/transformer combination.
4. The wattage of LED luminaires and LED light engines shall be the maximum rated input wattage of the system when tested in accordance with UL 1598, 2108, or 8750, or IES LM-79.
5. The wattage of LED tape lighting and LED linear lighting with LED tape lighting components shall be the sum of the installed length of the tape lighting times its rated linear power density in watts per linear feet, or the maximum rated input wattage of the driver or power supply providing power to the lighting system, with tape lighting tested in accordance with UL 2108 or 8750, or IES LM-79. The rules for determining lighting wattage are discussed in greater detail in Chapter 5 of this manual.

7.3 Mandatory Sign Lighting Controls

7.3.1 Indoor Sign Lighting Controls

§130.3(a)1

All indoor sign lighting other than exit sign lighting and sign lighting installed at healthcare facilities must be controlled with an automatic time-switch control or astronomical time-switch control.

These controls must meet the functionality requirements in §110.9. See Section 7.2.1 of this chapter for more information.

Example 7-1: Indoor Sign Lighting Controls

Question

Because the Energy Code require sign lighting to be controlled by an automatic time-switch control, will a sign inside a mall be required to automatically turn off during the day?

Answer

No, the sign is not required to be turned off during the day. The automatic time-switch control will allow the owner/occupant to program the sign to automatically turn on and off according to their needs.

7.3.2 Outdoor Sign Lighting Controls

§130.3(a)2

Outdoor sign lighting must meet the following requirements as applicable.

A. Controls for All Outdoor Sign Lighting

All outdoor sign lighting must be controlled with one of the following:

1. A photo control and automatic time-switch control
2. An astronomical time-switch control

Lighting for outdoor signs in tunnels and signs in large, permanently covered outdoor areas that are intended to be lit 24 hours per day and 365 days per year are exempt from this requirement.

B. Controls for Outdoor Sign Lighting That Is On Day and Night

Additional control requirements apply to outdoor sign lighting that is on during the day and night.

Outdoor sign lighting that is on day and night shall be controlled with a dimmer that provides the ability to automatically reduce sign lighting power by a minimum of 65 percent during nighttime hours.

Signs that are illuminated at night and for more than 1 hour during daylight hours shall be considered on both day and night.

Lighting for outdoor signs in tunnels and large covered areas that are intended to be illuminated both day and night are exempt from this requirement.

7.3.3 Demand Responsive Lighting Controls for Electronic Message Centers

§110.12(d)

An "electronic message center" (EMC) is a pixelated image producing an electronically controlled sign formed by any light source. Bare lamps used to create linear lighting animation sequences through the use of chaser circuits, also known as "chaser lights," are not considered an EMC.

EMCs that have a connected lighting load greater than 15 kW must have demand-responsive controls unless a health or life safety statute, ordinance, or regulation does not permit EMC lighting to be reduced. See Appendix D for guidance on compliance with the demand responsive control requirements.

7.4 Sign Lighting Power Requirements

7.4.1 Scope of Sign Lighting Power Requirements

The sign lighting power requirements apply to all internally illuminated signs, externally illuminated signs, unfiltered LEDs, and unfiltered neon, indoors or outdoors. Examples include cabinet signs, channel letters, lightboxes, backlit signs, illuminated billboards, and electronic message centers.

7.4.2 Applications Excluded From Sign Lighting Power Requirements

§140.8

The following sign lighting applications are not required to comply with the sign lighting power requirements:

A. Unfiltered Incandescent Lamps

Unfiltered incandescent lamps are lamps that are not part of an EMC, internally illuminated sign, or externally illuminated sign.

This exception applies only to portions of a sign that are unfiltered incandescent lamps. An "unfiltered sign" is defined in the Energy Code as a sign where the viewer perceives the light source directly as the message, without any colored filter between the viewer and the light source. Although internally illuminated signs are mentioned in this exception, it is only those portions of a hybrid sign consisting of unfiltered incandescent lamps that are excluded from the sign lighting power requirements.

B. Exit Signs

Exit signs are required to meet the requirements of the Appliance Efficiency Regulations.

C. Traffic Signs

Traffic signs are required to meet the requirements of the Appliance Efficiency Regulations.

7.4.3 Sign Lighting Power Compliance Options

There are two options for complying with the sign lighting power requirements:

- Maximum allowed lighting power (watts per square foot)
- List of compliant alternate lighting sources

7.4.4 Maximum Allowed Lighting Power

§140.8(a)

The maximum allowed lighting power compliance approach limits allowed sign lighting power based on the illuminated sign area. When using this approach, there are rules in the Energy Code for classifying the lighting technology used and determining luminaire power. Additional information on determining luminaire power is including in Section 7.2.2 of this chapter.

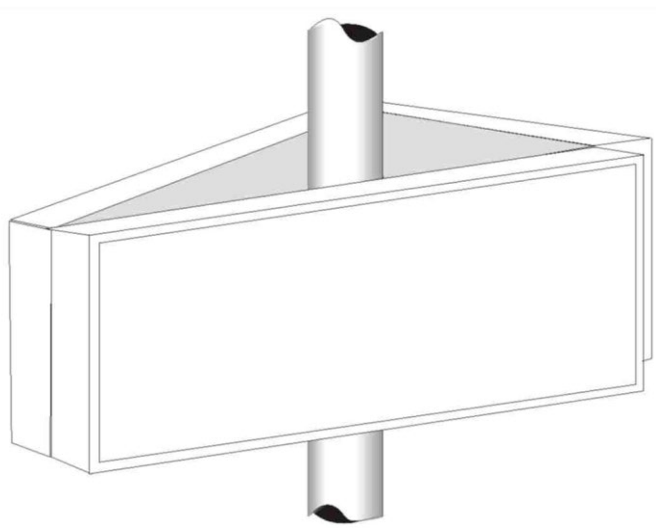
This compliance approach may be used for any light source type except unfiltered LED and unfiltered neon lighting, which must comply with the alternate lighting source compliance method described in Section 7.4.5.

The maximum allowed lighting power for internally and externally illuminated signs is calculated as follows:

A. Internally Illuminated Signs

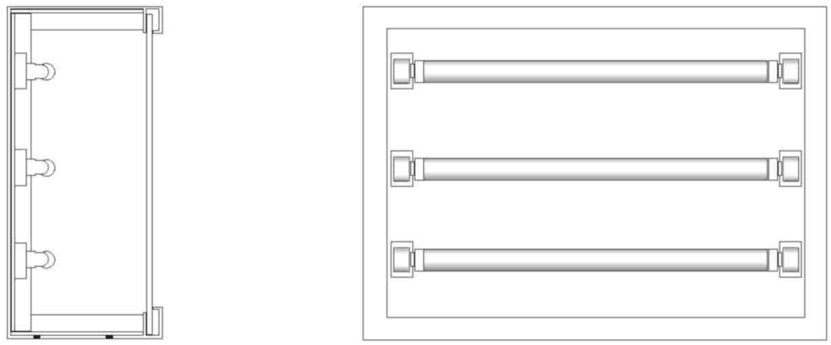
Internally illuminated signs (see Figures 7-1 and 7-2) are defined in the Energy Code as signs that are illuminated by a light source that is contained inside a sign where the message area is luminous, including cabinet signs and channel letter signs. The maximum allowed lighting power shall not exceed the product of the illuminated sign area and 12 watts per square foot of illuminated sign area. For double-faced signs (see Figure 7-3), only the area of a single face shall be used to determine the allowed lighting power.

Figure 7-1: Multifaced Sign



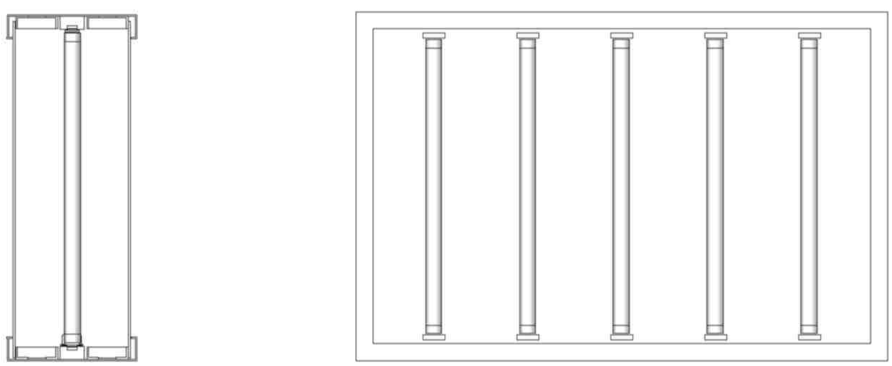
Source: California Statewide CASE Team

Figure 7-2: Single-Faced Internally Illuminated Cabinet Sign With Fluorescent Lamps and Translucent Face



Source: California Statewide CASE Team

Figure 7-3: Double-Faced Internally Illuminated Cabinet Sign With Fluorescent Lamps and Translucent Faces



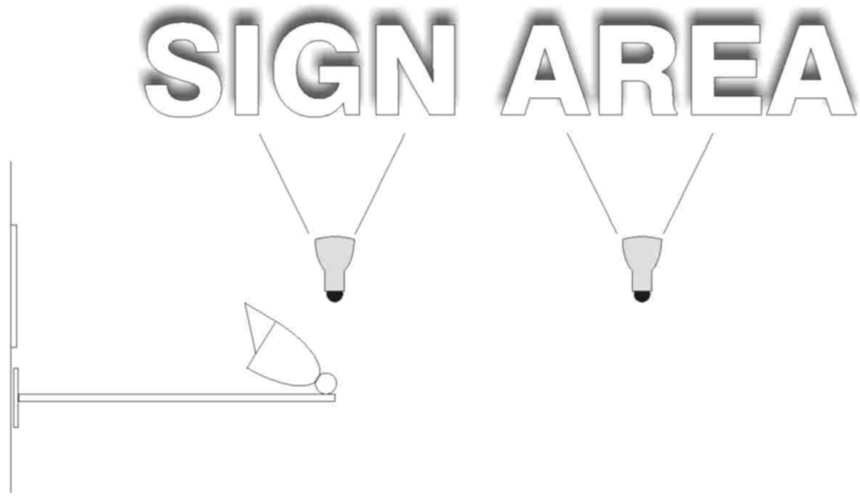
Source: California Statewide CASE Team

B. Externally Illuminated Signs

Externally illuminated signs (see Figure 7-4) are defined in the Energy Code as any sign or billboard that is lit by a light source that is external to the sign directed toward and shining on the face of the sign.

The maximum allowed lighting power shall not exceed the product of the illuminated sign area and 2.3 watts per square foot of illuminated sign area. Only areas of an externally lighted sign that are illuminated without obstruction or interference, by one or more luminaires, shall be used.

Figure 7-4: Externally Illuminated Sign Using Flood Lighting



Source: California Statewide CASE Team

7.4.5 Alternate Lighting Sources

§140.8(b)

The alternate lighting sources compliance approach specifies lighting technologies that may be used to meet the sign lighting power requirements. A sign is in compliance if it is equipped only with one or more of the following light sources:

1. High-pressure sodium lamps.
2. Metal-halide lamps that are:
   - Pulse start or ceramic served by a ballast that has a minimum efficiency of 88 percent or greater.
   - Pulse start that are 320 watts or less, are not 250 watts or 175 watts, and are served by a ballast that has a minimum efficiency of 80 percent.

     Ballast efficiency is the reference lamp power divided by the ballast input power when tested according to ANSI C82.6-2015.
3. Neon or cold cathode lamps with transformer or power supply efficiency greater than or equal to one of the following:
   - A minimum efficiency of 75 percent when the transformer or power supply rated output current is less than 50 mA.
   - A minimum efficiency of 68 percent when the transformer or power supply rated output current is 50 mA or greater.

     The ratio of the output wattage to the input wattage is at 100 percent tubing load.
4. Fluorescent lighting systems meeting either of the following requirements:

- Use only lamps with a minimum color rendering index of 80.
- Use only electronic ballasts with a fundamental output frequency not less than 20 kHz.

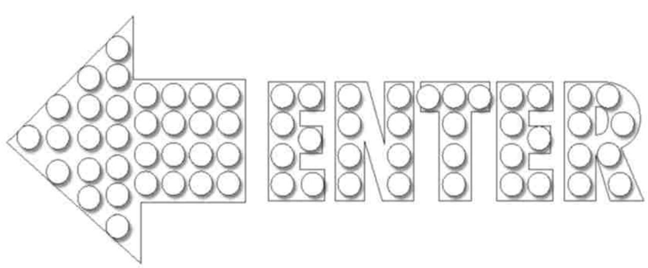
5. LEDs with a power supply efficiency of 80 percent or greater.
   - Single-voltage external power supplies that are designed to convert 120 volt AC input into lower voltage DC or AC output and which have a nameplate output power less than or equal to 250 watts and must comply with the applicable requirements for external power supplies in the Appliance Efficiency Regulations
6. Compact fluorescent lamps that do not contain a medium screw base socket (E24/E26).

7.4.6 Hybrid Signs

A sign may consist of components that are regulated and components that are not regulated. For example, a single sign structure may have a regulated internally illuminated cabinet, regulated externally illuminated letters attached to a brick pedestal, and unregulated unfiltered incandescent “chaser” lamps forming an illuminated arrow. Figure 7-5 shows an arrow, which is not part of an EMC using unfiltered incandescent lamps.

If the lamps are not covered by a lens, then only the control regulations (§130.3) apply to the sign. This type of unfiltered incandescent sign is not regulated by §140.8.

Figure 7-5: Unfiltered Incandescent Sign



Source: California Statewide CASE Team

Example 7-2: Neon and Cold Cathode Lighting

Question

Can I use neon or cold cathode lighting in my sign and comply with the Energy Code under Option 2 (compliant alternate lighting sources)?

Answer

Yes, neon and cold cathode lighting are allowed under the alternate light source compliance option, provided that the transformers or power supplies have an efficiency of 75 percent or greater for output currents less than 50 mA and 68 percent or greater for output currents 50 mA or greater.

Example 7-3: Indoor Sign Lighting in a Theater Lobby

Question

Do signs inside a theater lobby or other indoor environments need to comply with the sign requirements?

Answer

Yes, all illuminated signs must comply with either the maximum allowed lighting power or compliant alternate lighting sources compliance option.

Example 7-4: Alternate Lighting Sources – Incandescent Lamps

Question

My sign is equipped with both hardwired compact fluorescent lamps and incandescent lamps. Can my sign comply under the alternate lighting sources approach?

Answer

No. Because your sign is not exclusively equipped with -energy efficient technologies allowed under the alternate lighting sources approach (incandescent sources are not allowed), it must comply under the maximum-allowed lighting power compliance option. Your other option is to replace the incandescent sources with an option allowed under the alternate lighting sources, such as compliant LED, pulse start or ceramic metal halide, or fluorescent.

Example 7-5: Alternate Lighting Sources – Multiple Light Source Types

Question

My sign has an internally illuminated panel sign equipped with electronic ballasts and unfiltered 30 mA neon tubes above and below the panel sign having power supplies with 76 percent efficiency. Does this sign comply with the compliant alternate lighting sources option?

Answer

Yes, as long as the internally illuminated panel portion is illuminated with a compliant technology. This sign is essentially made up of three different signs (the panel sign and the two neon tubes); the entire sign complies as long as each part complies.

Example 7-6: Sign Lighting and Outdoor Lighting Zones

Question

Do outdoor lighting zone requirements apply to sign lighting?

Answer

No. Lighting for signs must meet the sign lighting requirements and does not need to meet the outdoor lighting requirements.

7.5 Additions and Alterations

§141.0(a)1, §141.0(b)2H

All new signs, regardless of whether they are installed in conjunction with an indoor or outdoor addition or alteration to a building or lighting system, must meet the requirements in §110.9, §130.0, §130.3, and §140.8.

7.5.1 Sign Alterations

§141.0(b)2M

Existing indoor and outdoor internally and externally illuminated signs that are altered as specified by §141.0(b)2M are required to meet the sign lighting power requirements in §140.8. Altered components of existing indoor and outdoor internally and externally illuminated signs must also meet the requirements in §130.0.

The sign lighting power requirements (either maximum-allowed power or alternate lighting sources) are triggered by alterations to existing internally or externally illuminated signs when any of the following occurs as result of the alteration, as specified in §141.0(b)2M:

- The connected lighting power is increased.
- More than 50 percent of the ballasts are replaced and rewired.
- The sign is relocated to a different location on the same site or on a different site.

These requirements are not triggered when only the lamps are replaced, the sign face is replaced, or the ballasts are replaced without rewiring.

Sign ballast rewiring that triggers the alterations requirements generally involves rewiring from parallel to series or vice versa, or when a ballast(s) is relocated within the same sign requiring relocating the wires. This does not include routine in-place ballast replacements.

Example 7-7: Replacing More Than 50 Percent of Ballasts

Question

We are replacing 60 percent of the ballasts in a sign. Must we replace the remaining ballasts in the sign to comply with the Energy Code?

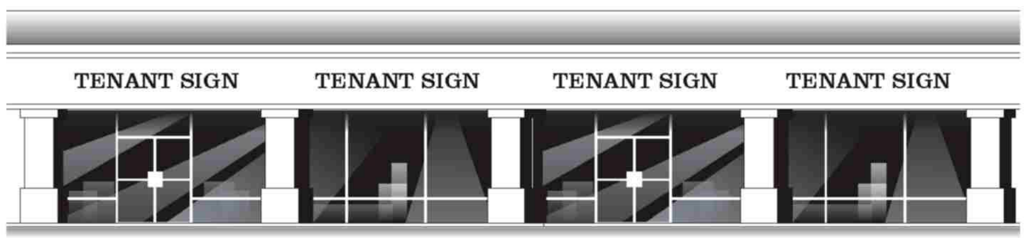
Answer

If more than 50 percent of the ballasts are being replaced, and the replacement involves rewiring the ballasts, then the requirements of §140.8 apply to the whole sign. If more than 50 percent of the ballasts are being replaced during regular maintenance, and the ballasts are not being rewired, then compliance with §140.8 is not required. However, when existing wiring will allow the direct replacement of a magnetic ballast with a high-efficiency, high-frequency electronic fluorescent ballast, the owner may wish to do this, even though it is not required.

Example 7-8: Altering Existing Signs

Question

I have a strip mall full of signs, and I will be altering some of them. Must I immediately bring all signs into compliance?



Answer

No. Only those signs in which at least 50 percent of the ballasts are replaced and rewired or those signs that are moved to a new location (on the same property or a different property) must comply with the sign lighting power requirements. All newly installed signs must comply with sign lighting control requirements and sign lighting power requirements.

7.6 Energy Compliance Documentation

7.6.1 Overview

This section describes the documentation required to demonstrate compliance with the sign lighting requirements.

When the permit application is submitted to the local enforcement agency, the applicant must submit certificate of compliance (NRCC-LTS-E) documentation. The person responsible for constructing the lighting system should submit the certificate of installation to the local enforcement agency after installation.

7.6.2 Inspection

The sign lighting compliance inspection is carried out along with other building inspections performed by the local enforcement agency. The inspector relies upon the plans (when required for signs) and the NRCC-LTS-E.

Note: For projects that involve building plans, the person with overall responsibility must ensure that the mandatory measures that apply to the project are listed on the plans. The principal designer can decide the format of this list.

7.6.3 Explanation of Compliance Document Numbering System

The following is an explanation of the Compliance Document Numbering System:

NRCC	Nonresidential (NR) Certificate of Compliance (CC)
LTS	Lighting (LT), Signs (S)
E	Enforcement Document (Developed primarily for the Enforcement Agency

7.6.4 Certificates of Compliance and Installation

The certificate of compliance documents demonstrate that the overall design of the regulated building or system complies with the Energy Code.

The plans examiner is responsible for verifying that these documents are submitted with the building plans and are complete when required. See Section 2.2.2 for more information about the certificate of compliance.

The NRCC-LTS-E is the nonresidential sign lighting certificate of compliance.

The certificates of installation primarily declare that what was installed matches the plans and certificates of compliance. The certificate of installation is signed by a person with an approved license.

Even if the design has errors and has specified incorrect features and devices, the installer is responsible to meet all the applicable requirements that he or she installs.

A copy of the completed, signed, and dated certificate of installation must be posted at the building site for review by the local enforcement agency in conjunction with requests for final inspection. See Section 2.2.5 for more information about certificates of installation.

The NRCI-LTS-01-E is the nonresidential sign lighting certificate of installation.

7.6.5 Lighting Control Systems Certificate of Installation

A certificate of installation is required when a lighting control system or EMCS is installed to comply with the sign lighting control requirements.

Before a lighting control system, including an EMCS, can be recognized for compliance with the lighting control requirements in the Energy Code, the following requirements must be met:

1. The person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices must sign and submit the certificate of installation.

2. If any of the requirements in the certificate of installation fail the installation tests, that application shall not be recognized for compliance with the Energy Code.

Table of Contents

8. Electrical Power Distribution

This chapter describes the Title 24, Part 6, Building Energy Efficiency Standards (Energy Code) requirements in Section 130.5 (§130.5) for electrical power distribution systems of nonresidential and hotel/motel occupancy buildings.

8.1 Overview

8.1.1 What's New for the 2022 Energy Code?

The significant change for electrical power distribution systems in the 2022 update to the Energy Code is demand-responsive controls for controlled receptacles. See Appendix D for demand-responsive controls and equipment.

8.1.2 Scope and Applications

The following requirements for electrical power distribution systems apply to all nonresidential and hotel/motel buildings. All the requirements in §130.5 for electrical power distribution systems are mandatory and are therefore not included in the energy budget for the performance compliance approach.

A. New Construction and Additions

The requirements of §130.5 apply to all newly constructed buildings and additions.

B. Alterations

The requirements for alterations to electrical power distribution systems are covered in §141.0(b)2P.

For alterations with new or replacement electrical service equipment, the requirements of §130.5(a) must be met. For alterations with entirely new or complete replacements of electrical power distribution systems, the requirements of §130.5(b) and (d) must be met. An electrical power distribution system can encompass service equipment, disconnecting means, overcurrent protection devices, feeders, circuit feeders, luminaires, receptacles, and electrical equipment such as switchboards, step-down transformers, and panelboards. For example, a building rehabilitation project where the entire electrical power distribution system is replaced is required to meet the requirements of §130.5(b) and (d).

For alterations (which include adding, modifying, or replacing) to feeders and branch circuits, the voltage drop requirements of §130.5(c) must be met. See Section 8.6 of this manual and §141.0(b)2P for the requirements for alterations to electrical power distribution systems.

C. Acceptance Testing, Commissioning, and Installation Certificates

Acceptance testing is required for demand-responsive controlled receptacles. A certificate of acceptance will be required to document that installed controls meet the requirements of the Energy Code.

See Section 8.8 for more information on compliance, installation, and acceptance documentation.

8.2 Service Electrical Metering Requirements

§130.5(a)

Projects are required to provide an electrical metering system that measures the instantaneous power usage and the cumulative electrical energy being used by the building. For metering systems that are not provided by the serving utility company, requirements apply based on the service kilovolt-ampere (kVA) rating as specified in Table 130.5-A and stated below:

1. For electrical service rated at any kVA, the meter must be able to measure instantaneous demand in kilowatts (kW) and energy consumed in kilowatt-hours (kWh) for a user-defined period.
2. For electrical service rated more than 250 kVA, the meter must be able to measure historical peak demand in kW.
3. For electrical services rated more than 1,000 kVA, the meter must be able to measure historical peak demand in kW and energy in kWh per rate period.

Utility-provided meters that indicate instantaneous demand in kW and consumption in kWh for a utility-defined period are sufficient to meet the requirements of this section and are not required to measure historical peak demand. If the utility-provided meter does not indicate instantaneous demand in kW and consumption in kWh for a utility-defined period, a separate meter must be installed that provides the full functionality required by §130.5(a) and Table 130.5-A of the Energy Code.

Each electrical service or feeder must have a permanently installed metering system that complies with these requirements. These terms are defined as follows:

1. "Service" is defined in §100.1 of the Energy Code as "the conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premise served."
2. "Feeder" is defined in Article 100 of the California Electrical Code as "all circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device."

This is not a requirement to install meters at the service and at each feeder. Rather, this requirement simply prevents unmetered service or feeder circuits from being installed within a building by requiring that a meter be installed at either the service level or, if not at the service level, at the feeder level.

Healthcare facilities are exempt from the service electrical metering requirement.

Example 8-1: Service Electrical Metering for Fire Pumps

Question:

There is one service to my building. The building fire pump is installed with the power connection tapped to the same service. Do I need to install another meter for the fire pump, in addition to the service metering already provided by the local utility?

Answer:

No, another meter for the fire pump is not required if it is using a service that is already connected to a meter. If it is not using a service that is already metered, then a separate meter may be required.

Example 8-2: Buildings With Multiple Electrical Services

Question:

There are two services provided by the local utility company to my building. Do both services require meeting the service electrical metering requirement?

Answer:

Yes, each electrical service must be metered in accordance with §130.5(a).

Example 8-3: Buildings With Separate Metering for Tenant Spaces 1

Question:

I own a nonresidential building with four tenant units. The building has one service, and there are four sets of meters and disconnect switches, one set for each tenant unit. The meters, which are provided by the utility company, provide the required kW and kWh information, and I intend to use the meters to meet the §130.5(a) requirement. Is this allowed by the regulations?

Answer:

Yes, metering each feeder instead of metering the service is allowed and is intended to address situations where one service feeds multiple tenants.

Example 8-4: Buildings With Separate Metering for Tenant Spaces 2

Question:

I have a building with multiple tenant spaces, and each tenant space is served by separate feeders. There is an individual meter for each feeder. Do I have to install a separate meter at the building service to fulfill the §130.5(a) requirement?

Answer:

No, it is not necessary to install a separate metering system for the service if a) there are individual meters for all the feeders, and b) all the meters meet the metering functionality requirements, based on the building service size, in Table 130.5-A of the Energy Code.

Example 8-5: Buildings With Multiple Tenant Spaces

Question:

I have a building with multiple tenant spaces, and each tenant space is served by a separate feeder. The building has one service with a utility metering system installed. Do I have to install a separate meter for each tenant space feeder to fulfill the §130.5(a) requirement?

Answer:

No, it is not necessary to install a separate metering system for each tenant space feeder if the building service utility metering system meets the functionality requirements in §130.5(a).

8.3 Separation of Electrical Circuits for Electrical Energy Monitoring

§130.5(b)

The separation of electrical circuits requirement allows monitoring the specific contributions of separate loads to the overall energy use of a building. By designing the electrical distribution system with separation of electrical loads in mind, energy monitoring can be readily set up and implemented without significant physical changes to the electrical installations. The goal is to be able to monitor the electrical energy usage of each load type specified in Table 130.5-B of the Energy Code. Building owners, facility management, and others can make use of such energy usage information to better understand how much energy has been used by each building system during a certain period. Further analysis of such energy information can help facilitate energy efficiency and related measures to improve building energy performance for building owners and operators.

Table 130.5-B specifies the load types that must be separated. These requirements vary depending on the kVA rating of the electrical service.

Healthcare facilities are exempt from the separation of electrical circuits requirement.

Example 8-6: Separation of Electrical Loads – Service Rated Less Than 50 kVA

Question:

My new nonresidential building is served by a single panel with a service less than 50 kVA.

What is the required separation of electrical circuits for this building?

Answer:

Renewable power sources and electric vehicle charging stations must be separated from other electrical load types and from each other, in accordance with the “Electrical Service rated 50kVA or less” column of Table 130.5-B and §130.5(b). The renewable power sources must be separated by group. All electric charging vehicle loads can be in aggregate.

If there are no renewable power sources or electric vehicle charging stations in this building, it is not required to separate the electrical circuits for electrical energy monitoring.

8.3.1 Compliance Methods

Electrical power distribution systems must be designed so that measurement devices can monitor the electrical energy usage of load types according to Table 130.5-B. However, for each separate load type, up to 10 percent of the connected load may be of another load type. The Energy Code allows any approach that provides the ability to measure the loads of the building separately.

The separation of electrical circuits requirement of §130.5(b) may be satisfied by any method that accomplishes this goal, including any of the following example methods:

A. Example Method 1 (See Example 8-7)

Switchboards, motor control centers, or panelboards may be separated by load type, allowing energy measurement of each load type independently and readily. This method must allow measurement and determination of the actual interval demand load value for each disaggregated load in the system.

This is a straightforward approach for measurement of each load type, as each switchboard, motor control center, or panelboard serves a single load type. Summation of the load measurement of the distribution equipment in accordance with the respective load type can result in the energy usage of each load type. This method is simple and straightforward in terms of the effort required in compiling the measurement data.

B. Example Method 2 (See Example 8-8)

Switchboards, motor control centers, or panelboards may supply other distribution equipment with the associated loads separated for each load type. The measured load for each piece of distribution equipment must be able to be added or subtracted from other distribution equipment supplying them. This method must allow measurement for each disaggregated load in the system.

This method allows distribution equipment to serve more than one load type while allowing the separate energy use of each load to be determined. More effort may be required in obtaining the energy usage of each load type.

C. Example Method 3 (See Example 8-9)

Switchboards, motor control centers, or panelboards may supply more than one load type as long as each branch circuit serves a single load type, and the equipment includes provisions for measuring individual branch circuits. For example, neighboring branch circuits in a panelboard may serve receptacles and fans, respectively, but the branch circuits cannot serve mixed load types.

D. Example Method 4

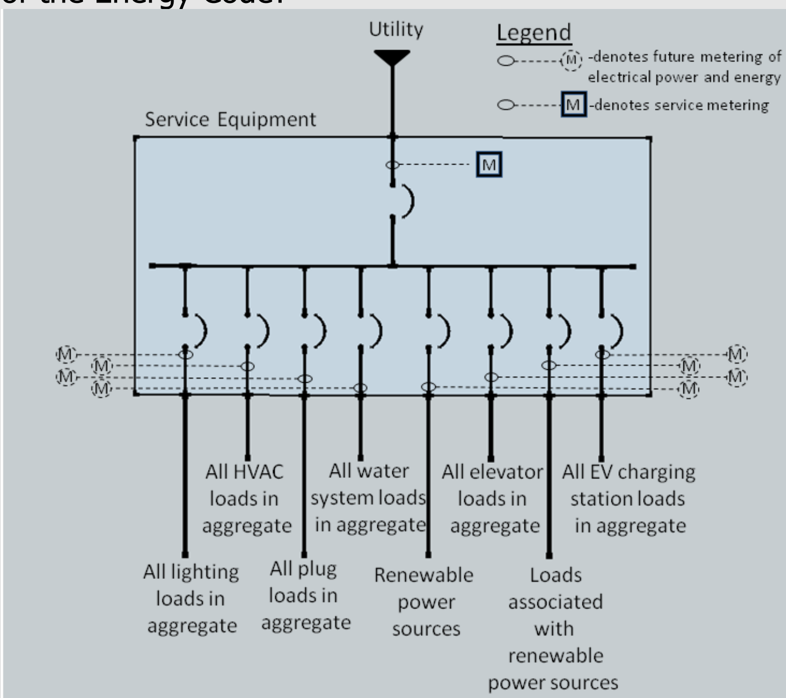
Buildings for which a complete metering and measurement system is provided so each load type can be measured separately.

This method allows a complete metering system to be used to meet the requirements of §130.5(b), provided that, at a minimum, the system measures and reports the loads called for in Table 130.5-B of the Energy Code. Such an installation goes beyond the requirement of the Energy Code as it meters and measures the power and energy usage of each load type. It provides benefits for building owners and operators by giving them a readily available tool for assessing the building energy usage as soon as the facility is turned over to them.

Example 8-7: Separation of Electrical Circuits by Panelboard

Question:

I am working on a new nonresidential building project with a service more than 50 kVA and less than 250 kVA. Following is the proposed separation of circuits for connecting different load types to the service equipment. Does this concept meet the requirements of the Energy Code?



Answer:

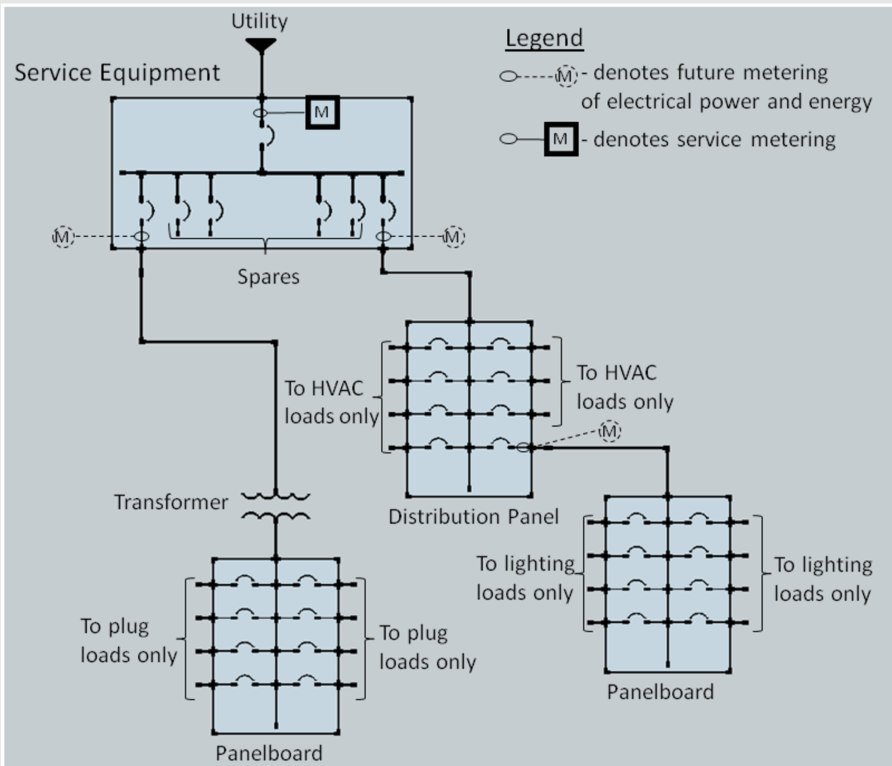
The proposed design meets the separation of electrical circuit requirement of §130.5(b) as there are separations of circuits for connecting different load types to the service equipment. There should be provisions including physical spaces for future setup of measurement devices for energy monitoring at each electrical installation location.

Example 8-8: Separation of Electrical Circuits by Panelboards and Subpanels

Question:

Part of my proposed design is to use a distribution panel serving HVAC loads, with the panel also feeding a lighting subpanel. There is a separate panelboard serving plug loads only.

Does this design meet the requirements of the Energy Code?



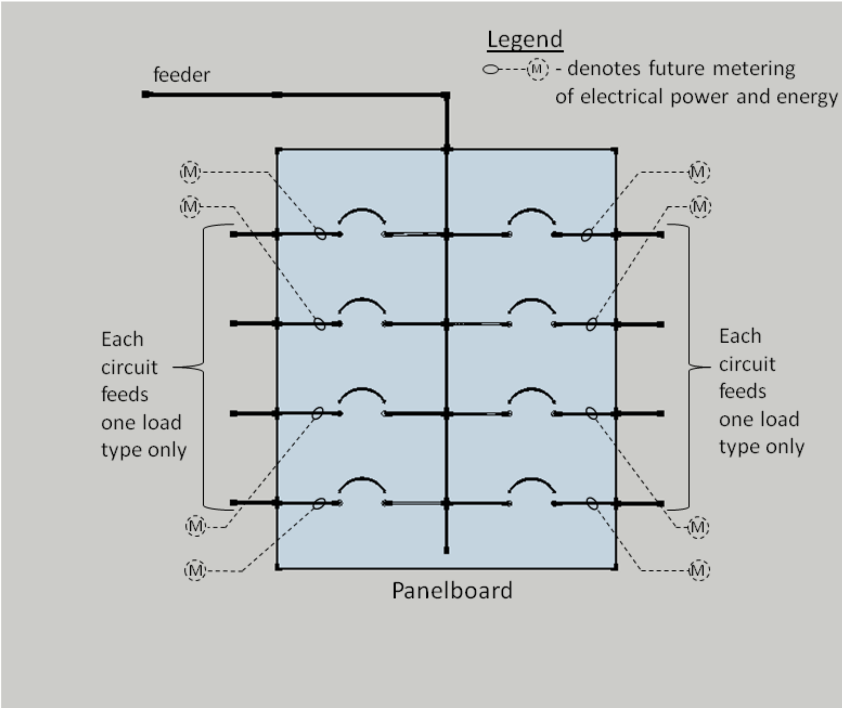
Answer:

The proposed design meets the separation of electrical circuit requirement of §130.5(b) as each load type in the building can be accounted for by addition and subtraction of the measured loads, as indicated in Method 2.

Example 8-9: Separation of Electrical Circuits by Branch Circuits

Question:

Can a panelboard with provisions allowing branch circuit energy monitoring be used to meet the separation of electrical circuits requirement? Each circuit would serve no more than one load type.



Answer:

The proposed design allows each load type to be separately measured at the branch circuit, so it meets the requirements of §130.5(b).

8.3.2 Application Considerations

The Energy Code allows the use of conventional panelboards, motor control centers, and other standard wiring methods for meeting the separation requirement. The requirement may also be met by a well-planned wiring approach, such as connecting all HVAC units to a single feeder from the service using a combination of through feeds and taps. The regulations are intentionally written to specify the "what" without prescribing the "how," providing flexibility.

In a "typical" small building with a service size of 50 kVA or less, separation of electrical loads is not required for the building loads, except for any renewable power sources (solar PV systems) and electric vehicle charging stations installed at the building.

In buildings with a service size between 50 kVA and 250 kVA, separate risers for lighting, receptacles/equipment, and HVAC are allowed to be used for meeting the separation of electrical circuits requirement. Large loads or groups of loads, such as an elevator machine room or a commercial kitchen, may be connected to panelboards or motor control centers served by a dedicated feeder, and the electrical power and energy of the entire group of loads can be measured by metering the feeder.

For buildings with a service size more than 250 kVA, lighting and plug loads are required to be separated by floor, type, or area. In a single-story building, all the lighting loads could be fed from a single panel, and all the plug loads could be fed from another panel (or, alternatively, both types of loads could be fed from one panel with provision to allow for future metering for each load type – metering data further be further organized, compiled, and viewed with software or mobile applications for each load type).

In a multistory building, a simple way to comply would be to install a separate lighting panel and a separate plug-load panel for each floor of the building. However, it would also be acceptable (and may be more useful) to divide the load according to which area of the building it serves (such as office, warehouse, and corridors) or by the type of light fixture (for example, metal-halide, fluorescent, dimmable, and fixed-output). For example, the first- and second-floor office lights could be fed from the same panel, while the warehouse lights are fed from a second panel. Dividing the load by area or type instead of by floor is more likely to yield useful information when the loads are analyzed in an energy audit. All the above approaches are acceptable methods of complying with the Energy Code.

8.4 Voltage Drop Requirements

§130.5(c)

The voltage drop requirement is as follows:

Voltage drop of feeder + voltage drop of branch circuit must be ≤ 5%

The maximum combined voltage drop on both installed feeder conductors and branch circuit conductors to the farthest connected load or outlet must not exceed 5 percent. This is the steady-state voltage drop under normal load conditions.

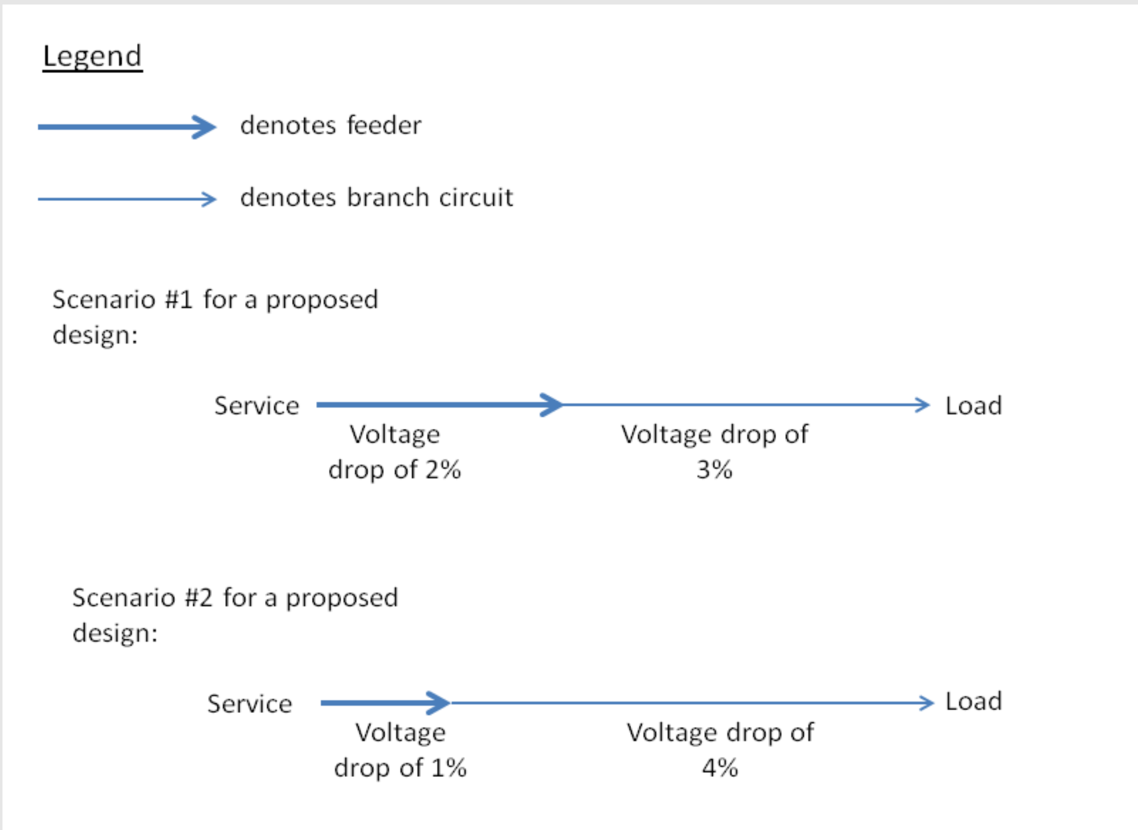
The voltage drop permitted by California Electrical Code Sections 647.4, 695.6, and 695.7 are exempted from this requirement.

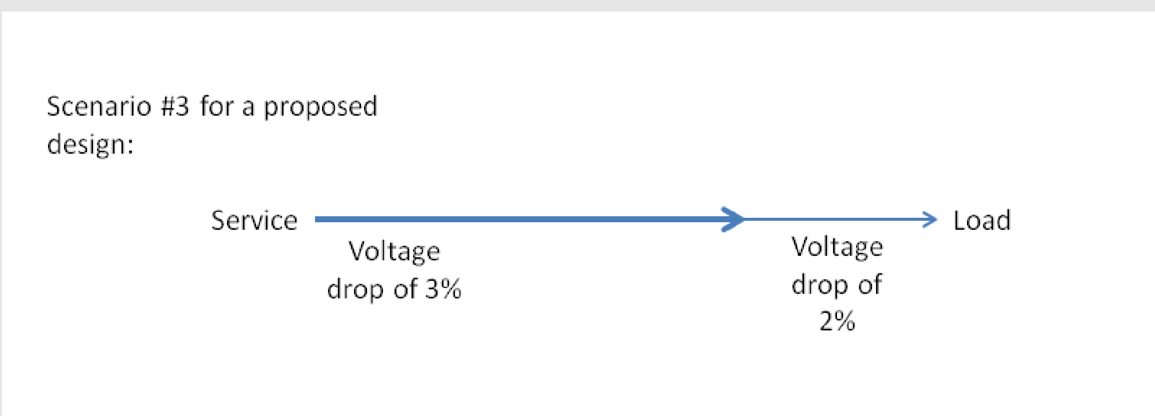
Voltage drop losses are cumulative, so voltage drop in feeders and voltage drop in branch circuits contribute to the load at the end of the branch circuit. Excessive voltage drop in the feeder conductors and branch circuit conductors can result in inefficient operation of electrical equipment.

Compliance documentation must include voltage drop calculations for each installed feeder and branch circuit conductor showing that the combined voltage drop for the farthest load for each type of load will not exceed 5 percent.

Example 8-10: Voltage Drop Calculations

Question: Do the following proposed designs meet the voltage drop requirement of §130.5(c)?





Answer:

All the above proposed design scenarios meet the voltage drop requirement of §130.5(c), as the combined voltage drop of the feeder and the branch circuit does not exceed 5 percent.

Example 8-11:

Question: Do healthcare facilities have to comply with the voltage drop requirement?

Answer:

Healthcare facilities must meet the voltage drop requirement in §130.5(c).

8.5 Circuit Controls and Controlled Receptacles for 120-Volt Receptacles

§130.5(d)

Healthcare facilities are exempt from the controlled receptacle requirements.

"Office plug loads" are the loads with the largest power density (W/ft^2) in most office buildings. The Energy Code requires controlled and uncontrolled 120-volt receptacles in lobbies, conference rooms, kitchen areas in office spaces, copy rooms, and hotel/motel guest rooms. Controlled receptacles allow plug loads to be turned off automatically when the space is unoccupied, resulting in energy savings.

All controlled receptacles must be marked to differentiate them from uncontrolled receptacles.

Either circuit controls or controlled receptacles can be used for meeting the requirements of Section 130.5(d).

Either of the following is required for compliance:

1. At least one controlled receptacle located within 6 feet of each uncontrolled receptacle
2. Split-wired receptacles that provide at least one controlled outlet

The controlled receptacle requirement does not require that there be one controlled receptacle for each uncontrolled receptacle.

In open office areas where receptacles are installed in modular furniture, at least one controlled receptacle must be provided for each workstation. Any controlled circuits already built into the building system can be used to meet the requirement.

Controlled receptacles or circuits must be capable of automatically switching off when the space is not occupied. See Section 8.5.1 for example approaches of using automatic means for shutting off controlled receptacles. An automatic time switch with manual override may be used for meeting the requirement. Occupant sensing controls may also be used.

Plug-in strips and other plug-in devices do not meet this requirement, but a hardwired power strip controlled by an occupant sensing control does.

Controlled receptacles are not required in the following situations:

1. Receptacles in kitchen areas specifically for refrigerators and water dispensers
2. Receptacles specifically for clocks. (The receptacle must be mounted 6’ or more above the floor to meet this exception.)
3. Receptacles in copy rooms specifically for network copiers, fax machines, audio-visual equipment, and data equipment other than personal computers
4. Receptacles on circuits rated more than 20 amperes
5. Receptacles connected to an uninterruptible power supply that are intended to be in use 24 hours per day, every day of the year, and are marked to distinguish them from other standard uncontrolled receptacles or circuits.

8.5.1 Application Considerations

The following are example approaches to meeting the controlled receptacle requirements:

A. Private Offices, Conference Rooms, and Other Spaces With Periodic Occupancy

Occupant-sensing controls that are part of a lighting control system may be used to control general lighting and receptacles. For example, a common occupancy sensor can control general lighting and receptacles, with auxiliary relays connected to the lights and the controlled receptacles to provide the needed functionality.

B. Lobbies, Break Rooms, and Other Spaces With Frequent Occupancy During Business Hours

Astronomical time-switch controls, with either a vacancy sensor or switch override, can be used to control receptacles. Programmable relay panels or controllable breakers can be used, or, for simpler projects, a combination of vacancy sensors and programmable time switches can accomplish the same task. If vacancy sensing is used, controls will likely need to be room-by-room or space-by-space, but if time-switch control with manual override is used, whole circuits may be controlled together.

C. Open Office Areas

Receptacles in open office areas can be controlled by the automatic shutoff system of the building or by controls integrated into the modular furniture systems. Automatic time-switch controls with relays or controllable breakers, and manual override switches, may be used for zones within an open office space. A system using vacancy sensors might also be considered if sensors can be added as needed to address partitioning of the workstations (thus ensuring proper operation). Systems contained within workstation systems are an acceptable alternative provided that they are hardwired as part of the workstation wiring system.

D. Networked Control Systems and Building Automation Systems

Most advanced lighting and energy control systems can be easily designed to accommodate receptacle controls.

Certain office appliances, such as computers, need to be powered continuously during office hours to provide uninterrupted service. These would be connected to uncontrolled receptacles. Other appliances, such as task lamps, fans, heaters, and monitors, do not need to be powered when occupants are not present. These controllable loads would be plugged into the controlled receptacles to ensure they are automatically shut off and to prevent any unnecessary standby power draw.

In open office areas, it is advisable to implement vacancy sensor controls at each workstation or cubicle to maximize the opportunities of shutoff controls. Modular office system furniture is usually equipped with more than one internal electrical circuit, and some of these circuits can be dedicated for controllable plug loads.

8.5.2 Demand Response

§130.5(e), 110.12(e)

When demand-response controls are required for lighting systems, controlled receptacles must comply with demand-responsive control requirements in §110.12. Controlled receptacles must be capable of automatically turning off all connected loads in response to a demand-response signal.

Spaces where health or life safety statute, ordinance, or regulation does not permit receptacles to be automatically controlled are exempt from this requirement.

See Appendix D of this manual for guidance on compliance with the demand-responsive control requirements.

8.6 Additions and Alterations

Additions are like newly constructed buildings, and all requirements of §130.5 apply to additions. For additions, the discussions in the previous sections of this chapter apply.

A summary of requirements for alterations of electrical power distribution systems is as follows:

1. **Service Electrical Metering –** New or replacement electrical service equipment shall meet the requirements of §130.5(a). Alterations that do not install new service equipment or replace existing service equipment are not held to these requirements. This requirement applies only to the service and does not apply to new or replaced feeders.
2. **Separation of Electrical Circuits for Electrical Energy Monitoring –** For entirely new or complete replacement of electrical power distribution systems, the entire system shall meet the applicable requirements of §130.5(b). Alterations that do not install an entirely new power distribution system or

completely replace an existing power distribution system are not held to these requirements.

3. **Voltage Drop –** Alterations of feeders and branch circuits that include any addition, modification, or replacement of both feeders, and branch circuits must meet the requirements of §130.5(c). Alterations that do not include **both** the feeder and branch circuit are not held to these requirements. For example, if a branch circuit is replaced but the feeder to the panel board is not touched, the feeder and branch circuit would not need to meet the 5 percent maximum voltage drop requirement.

   The same exceptions for voltage drop permitted by the California Electric Code apply for alterations.

4. **Circuit Controls for 120-Volt Receptacles and Controlled Receptacles –** For entirely new or complete replacement of electrical power distribution systems, the entire system shall meet the applicable requirements of §130.5(d) and §130.5(e).

Example 8-12: Alterations Limited to Adding New Feeders

Question:

I have an existing building with multiple tenant spaces, and each tenant space is served by separate and individual feeders. I am breaking up one large tenant space into two smaller ones. I plan to reuse the existing feeder and add a new feeder. Is it mandatory to provide a meter for the new feeder?

Answer:

No, this requirement is limited to new or replacement electrical service equipment and does not apply to feeders. For alterations involving only new or replacement feeders, there is no requirement to install a meter for the newly added or replaced feeder.

Example 8-13: Alterations With Entirely New or Complete Replacement Electrical Power Distribution Systems

Question:

Does the language "entirely new or complete replacement" in §141.0(b)2Pii and iv refer to the entire building or just the altered areas of the building?

Answer:

This language applies to the electrical power distribution system within the building and therefore effectively refers to the entire building. A modification of only part of the electrical power distribution system does not trigger the requirement.

For example, the scope of work for a tenant improvement project does not typically involve installing or replacing the entire electrical power distribution system; therefore, separation of electrical circuits would not typically be required. However, first-time buildouts of tenant spaces must meet requirements for newly buildings if the local enforcement agency classifies first-time buildouts as a newly constructed building or space. See Example 8-14 for more information.

Another example is a project where a portion of the system is upgraded for greater electrical capacity and the work scope includes replacement of panelboards, associated feeders, and overcurrent protection devices. This is not a complete replacement or entirely new electrical power distribution system, since there is existing equipment that is not changed or replaced.

Example 8-14: First-Time Buildouts in Shell Spaces

Question:

Do controlled receptacle requirements and separation of electrical circuits requirements apply to first-time tenant improvements in a building with multiple tenant shells?

Answer:

Yes. If the local enforcement agency classifies first-time buildouts (first-generation tenant improvement) as a newly constructed building or space, it must meet all requirements for newly constructed buildings. These requirements include controlled receptacles and separation of electrical circuits in §130.5. Check with the local enforcement agency for its policy on first-generation tenant improvements.

A tenant improvement to an existing space that has been previously developed must meet the alteration requirements for controlled receptacles and separation of electrical circuits in §141.0(b)2Piv. Controlled receptacle and separation of electrical circuit requirements will apply only to alterations where there is an entirely new or complete replacement of the electrical power distribution system for the entire building.

8.7 Equipment Requirements – Electrical Power Distribution Systems

The Energy Code specify in §110.11 that low-voltage dry-type distribution transformers may be installed only if the manufacturer has certified model information to the Energy Commission as required by the Title 20 Appliance Efficiency Regulations. In addition, §110.1 specifies that appliances regulated by the Title 20 Appliance Efficiency Regulations may be installed only if the appliance fully complies with those efficiency regulations, and both medium-voltage dry-type and liquid-immersed transformers are included in the Appliance Efficiency Regulations.

This means that builders, electrical contractors, electrical engineers, or owners who wish to install a distribution transformer will generally need to check the Appliance

Efficiency Database to confirm that the model they are selecting has been certified by the manufacturer as required by law. A link to the database is below:

https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx

The following types of transformers are exempt from certification requirements, and are not required to be listed in the database:

1. Autotransformers
2. Drive (isolation) transformers
3. Grounding transformers
4. Machine-tool (control) transformers
5. Nonventilated transformers
6. Rectifier transformers
7. Regulating transformers
8. Sealed transformers
9. Special-impedance transformers
10. Testing transformers
11. Transformers with tap range of 20 percent or more
12. Uninterruptible power supply transformers
13. Welding transformers.

8.8 Electrical Power Distribution Systems Compliance Documents

8.8.1 Overview

This section describes the compliance documentation (compliance form[s]) required for compliance with the Energy Code requirements regarding electrical power distribution systems.

At the time a building permit application is submitted to the local enforcement agency, the applicant also submits plans and energy compliance documentation.

This section is addressed to the person preparing construction and compliance documents, and to the local enforcement agency plan checkers who are examining those documents for compliance with the Energy Code.

8.8.2 Compliance Documentation and Numbering

List of compliance documents for electrical power distribution systems is as follows; the documents are downloadable from California Energy Commission website under the “Compliance Manuals and Compliance Documents” section.

- NRCC-ELC-E, Certificate of Compliance, Electrical Power Distribution Systems
- NRCI-ELC-E, Certificate of Installation, Electrical Power Distribution Systems

- NRCA-LTI-04-A, Certificate of Acceptance, Demand Responsive Controls

A certificate of acceptance (NRCA-LTI-04-A) will be required for projects that must meet the demand responsive controlled receptacle requirements in §130.5€ and §110.12(e). Acceptance testing for demand responsive controlled receptacles must be completed by a certified lighting controls acceptance test technician.

The following is the numbering scheme of the compliance documentation forms:

NRCC	Nonresidential Certificate of Compliance
NRCI	Nonresidential Certificate of Installation
NRCA	Nonresidential Certificate of Acceptance
ELC	Electrical power distribution systems
LTI	Lighting, indoor
E	Primarily used by local enforcement authority
A	Primarily used by acceptance tester

A permit applicant should use a single compliance form for each building included in the permit application. This ensures clarity of information for the permit and plan check process. The person who is eligible under Division 3 of the Business and Profession Code to accept responsibility for the building design can sign the compliance form.

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9 Photovoltaic, Community Shared Solar, Battery Storage, and Solar-Ready Buildings

9.1 Overview

Chapter 9 describes the compliance requirements for photovoltaic (PV) systems, battery storage systems, and solar readiness for newly constructed nonresidential, and hotel/motel buildings. The prescriptive PV and battery storage requirements for particular non-residential buildings determine the standard design energy budgets for the performance compliance method. Additional total TDV or hourly source energy compliance credit is available for installation of PV and battery storage systems that exceed the energy performance of the prescriptive requirement. For both prescriptive and performance compliance, the PV system must meet the requirements of JA11 Qualification Requirements for Photovoltaic Systems, and the battery storage system must meet the requirements of JA12 Qualification Requirements for Battery Storage Systems.

The Energy Standards allow the requirements for photovoltaics to be offset by community-shared solar electric generation. The community-shared solar program must be approved by the Commission. For more information, please see section 9.4.

The requirements for solar-ready buildings are mandatory measures for newly constructed nonresidential and hotel/motel buildings that do not have a PV system because the building either qualifies for an exception in Section 140.10(a) or complies with the PV requirements using community shared solar as a performance compliance option. The solar-ready requirement must be addressed when designing the roof and associated equipment of a building. The intent is to reserve a penetration-free and shade-free portion of the roof for the potential future installation of a solar energy system. There are no requirements to install panels, conduit, piping, or mounting hardware.

For information about requirements and compliance options for solar water heating systems, please see Chapter 4.

9.1.1 What's New for 2022

9.1.1.1 Prescriptive Measures

Photovoltaic (PV) and battery storage systems are now required for some nonresidential building categories and hotel/motel buildings. See Section 9.2 for details.

9.1.1.2 Performance Compliance

PV and battery storage system requirements also can be met by using the performance approach. See Section 9.3.1. A community-shared solar electric generation system, or other renewable electric generation system, and/or community shared battery storage system can be used to offset the solar electric generation system or battery storage system TDV energy required to comply using the performance compliance method. See Section 9.4.

9.2 Prescriptive Requirements for Photovoltaic System

9.2.1 Photovoltaic System Size – Nonresidential and Hotel/Motel

§140.10(a) and §170.2(g)

To comply with the prescriptive requirements the following building types are required to have a PV system installed unless the building qualifies for an exception.

- Grocery
- Office, Financial Institutions, Unleased Tenant Space
- Retail
- School
- Warehouse
- Auditorium, Convention Center, Hotel/Motel, Library, Medical Office Building/Clinic, Restaurant, Theater

For all building types listed in Table 9-1, the PV size in kW dc must be not less than the smaller of the PV system size determined by Equation 9-1, or the total of all available Solar Access Roof Areas (SARAs) multiplied by 14 W/ft^2.

SARAs include the area of the building roof, covered parking areas, carports, and all other newly constructed structures that are capable of structurally supporting a PV system per Title 24, California Code of Regulations, Part 2, (California Building Code or CBC) Section 1511.2. SARA does not include any roof area with less than 70 percent annual solar access, occupied roofs as specified by CBC Section 503.1.4, or roof space that is not available due to compliance with other building code requirements if confirmed by the Executive Director.

The annual solar access is the ratio of solar insolation including shading to the solar insolation without shading. Annual solar access is determined by dividing the total annual solar insolation (accounting for shading obstructions) by the total annual solar insolation if the same areas were unshaded by those obstructions. For all roofs, all obstructions including those that are external to the building, and obstructions that are part of the building design and elevation features may be considered for the annual solar access calculations. Refer to Exceptions for Reduced Solar Zone Due to Shade in Section 9.6.2 for an example of how to calculate annual solar access.

Equation 9-1

kWPV required = (CFA x A)/1000

WHERE:

kWPV = kWdc size of the PV system

CFA = Conditioned floor area

A = Capacity factor from Table 9-1

Mixed-occupancy buildings, where 80 percent or more of the floor area is for one, or more, of the building types listed in Table 9-1, must comply with these prescriptive requirements. Where the building includes more than one of the space types listed in Table 9-1, the total PV system capacity for the building shall be determined by applying Equation 9-1 to each of the listed space types and summing the capacities determined for each.

Table 9-1: PV Capacity Factors

Climate Zone	1,3,5,6	2,4,6-14	15
Grocery	2.62	2.91	3.53
High Rise Multifamily	1.82	2.21	2.77
Office, Financial Institutions, Unleased Tenant Space	2.59	3.13	3.8
Retail	2.62	2.91	3.53
School	1.27	1.63	2.46
Warehouse	0.39	0.44	0.58
Auditorium, Convention Center, Hotel/Motel, Library, Medical Office Building/Clinic, Restaurant, Theater	0.39	0.44	0.58

Factor A – Minimum PV Capacity (W/ft² of conditioned floor area)

Source: California Energy Commission

9.2.2 Photovoltaic System Exceptions – Nonresidential, Hotel/Motel

§140.10(a)

There are five allowable exceptions to the prescriptive PV requirements as listed below.

Exception 1: No PV system is required if the total SARA is less than 3 percent of conditioned floor area.

Exception 2: No PV system is required when the minimum PV system is less than 4 kWdc.

Exception 3: No PV system is required if the SARA is less than 80 contiguous square.

Exception 4: Buildings with enforcement-authority-approved roof designs, where the enforcement authority determines it isn't possible for the PV system, including panels, modules, components, supports, and attachments to the roof structure, to meet the snow load requirements of Ch. 7 in the American Society of Civil Engineers (ASCE) Standard 7-16.

Exception 5: No PV is required for multi-tenant buildings in areas where a load serving entity does not provide either a virtual net metering (VNEM) or community solar program.**Example 9-1: PV Exceptions**

Question

I am designing a warehouse with less than 4,000 square feet of conditioned floor area in Climate Zone 12. Is PV required for my building?

Answer

First determine the kWdc required by using Equation 9-1 and Table 9-1. A warehouse in Climate Zone 12 has a PV capacity factor of 0.44.

kWPV required = (CFA x A)/1000 = (4,000 x 0.44) / 1000 = 1.76 kWdc

Since the required PV is less than 4 kWdc, it qualifies for Exception 2, and a PV system is not required.

Example 9-2:

Question

The local utility serving my new multitenant building does not offer VNEM or provide any community solar program. Am I required to find a third-party provider for VNEM?

Answer

No. Since the local utility do not offer either VNEM or community solar, PV is not required under Exception 5.

9.2.3 Joint Appendix 11 (JA11) Requirements

The installed PV system whether using the prescriptive or performance approach must meet the applicable requirements specified in JA11.

9.2.3.1 System Orientation

For prescriptive path compliance, a PV system with module pitches greater than 2:12, or 10 degrees, must be oriented with an azimuth between 90 to 300 degrees measured clockwise from true north. Module pitches smaller than 2:12 or less than 10 degrees (low-slope) can be installed in any orientation since the azimuth of low-slope modules has an insignificant impact on array performance.

When using the performance approach, the array may be oriented in any direction, including due north; however, the more the orientation deviates from the optimum orientation of southwest, the worse the system performs, resulting in a larger PV system size to be needed to achieve compliance. It is best to orient the panels as close to southwest as possible to maximize the system performance with the smallest array size.

There are two options for using a California Flexible Installation approach to simplity computer compliance modeling. To use the California Flexible Installation 1 (CFI1) , the PV array must be installed between 150 to 270 degrees from true north, with all modules at the same tilt as the roof for pitches up to 7:12. When the CFI2 option is selected in the performance calculation, the PV array can be installed in a larger azimuth range; the PV array must be installed between 105 and 300 degrees from true north, with all modules at the same tilt as the roof for pitches up to 7:12. When selecting CFI2, the performance of the proposed system is derated by approximately 10 percent, which results in a larger PV size being necessary to comply.

If the PV array does not meet either CFI1 or CFI2, then the actual orientation and tilt of the PV array shall be described.

9.2.3.2 Shading

Shading from obstructions must be limited to meet the performance or prescriptive requirements. Any obstruction located north of the array does not need to be considered. Obstructions include the following:

- Any vent, chimney, architectural feature, mechanical equipment, or other obstruction that is on the roof or any other part of the building.
- Any part of the neighboring terrain.
- Any tree that is mature at the time of installation of the PV system.
- Any tree that is planted on the building lot or neighboring lots or planned to be planted as part of landscaping for the building. (The expected shading shall be based on the mature height of the tree.)
- Any existing neighboring building or structure.

- Any planned neighboring building or structure that is known to the applicant or building owner.
- Any telephone or other utility pole that is closer than 30 feet from the nearest point of the array.

Example 9-3: Shading

Question:

What would be the impact of shading on the PV sizing requirement?

Answer:

Prescriptively the PV array cannot have any shading, and the weighted average annual solar access as measured by an approved solar assessment tool must be at least 98 percent by panel count. Under the performance path, there is no minimum requirement for annual solar access; however, the increase in shading (lower annual solar access) will necessitate a larger PV size to meet the same TDV budget as a smaller unshaded PV system.

9.2.3.3 Solar Access Verification

A solar assessment tool that is approved by the executive director must be used to demonstrate the shading conditions of the PV system or to claim an exception based on limited amount of solar access.

The installer must provide documentation that demonstrates the actual shading condition of the installed PV system using an approved solar assessment tool. To be certified by the executive director, the solar assessment tool:

- Must calculate the annual solar access percentage of each solar array and a weighted average of the PV system. The calculation must include all known obstructions, including any tree that is planted on the building lot or neighboring lots or planned to be planted as part of landscaping for the building.
- Must not include horizon shading in the calculation by default.
- Must produce a shade report with a summary of the PV system, including the address of the project, individual array panel count, orientation, annual solar access percentage, and a weighted average of the PV system as a whole.
- Must ensure that annual solar access percentage values are comparable to on-site measurements if the model shading condition of the tool is based on satellite or aerial images. Documentation must be provided to the CEC as proof.

9.2.3.4 Remote Monitoring Capability

The PV system must have a web portal and a mobile device application that enables the building owner, manager, or occupants to monitor the performance of their PV system to identify, report, and correct performance issues with the panels, inverters, shading, or other issues that may adversely impact the performance of the PV system. At a minimum, the occupants must have access to the following information:

- The nominal kW rating the PV system
- Number of PV modules and the nominal watt rating of each module
- Hourly (or 15-minute interval), daily, monthly, and annual kWh production in numeric and graphic formats for the system
- Running total of daily kWh production
- Daily kW peak power production
- Current kW production of the entire PV system

9.2.3.5 Additional Requirements

In addition to the requirements above, the PV system must also meet the following requirements in JA11:

Interconnection Requirements: All inverters in the PV system must comply with all requirements in the CPUC Electric Tariff Rule 21. Rule 21 requires that inverters have certain capabilities to ensure proper operation of the electrical grid as more renewables are interconnected. The inverters must perform functions that can autonomously contribute grid support during excursions from normal operating voltage and frequency system conditions by providing dynamic reactive/real power support, voltage and frequency ride-through, ramp rate controls, communication systems with ability to accept external commands, and other functions.

Certificates and Availability: The PV installer shall certify on the certificate of installation that all provisions of JA11 are met and provide a solar assessment report meeting one of the following conditions:

- A satellite, drone, or other digital image used in the solar assessment report must be created and dated after the PV system is installed.
- If the satellite, drone, or other digital image used in the solar assessment report is dated before the PV is installed, additional on-site pictures must be attached to clearly show that the installed system matches the system modeled in the solar assessment report.

The certificate of installation must be available on the building site for inspections.

Enforcement Agency Responsibilities: The local enforcement agency must verify that the certificate of installation is complete and correct, and uploaded into a Commission-approved registry.

Example 9-4: Remote Monitoring

Question:

How do I implement monitoring to meet JA11.5.1 including the current reading?

Answer:

There are several options. Many inverters can connect to the building owner's internet, via ethernet or wireless or both. Others use independent cellular connections. For cellular, the data should be updated to the monitoring portal periodically as allowed by the cellular plan

9.3 Performance Approach Compliance for Photovoltaic Systems

9.3.1 Energy Budget Calculation

The performance approach allows for modeling of the PV system performance by taking into account the PV system size, climate, panel orientation, panel and inverter efficiency, and shading characteristics. For nonresidential and hotel/motel buildings, the standard design PV system size is determined by the smaller of the PV system size determined by Equation 9-1, or the total of all available Solar Access Roof Areas (SARAs) multiplied by 14 W/ft². The performance method allows for modeling different PV sizes, solar thermal systems, more energy efficiency measures, additional battery storage and other demand-response measures.

9.3.2 Exceptions to PV Requirements

The allowable exceptions to the prescriptive PV requirements listed in 9.2., for nonresidential, hotel/motel and high-rise multifamily buildings or low-rise multifamily buildings, respectively, can also be used under the performance approach. The user must select the appropriate exception in the software and provide documentation to the building department with the building permit application.

9.3.3 Additional Requirements

The installed PV system must meet the applicable requirements specified in JA11.

Example 9-5: Efficiency Tradeoff

Question:

Does the performance path allow tradeoffs between PV systems and energy efficiency measures? How about tradeoffs between a PV system that is coupled with a battery storage system and energy efficiency measures?

Answer:

Beginning with the 2019 Standards, the performance path no longer allows installing a larger PV system in exchange for less energy efficiency measures for showing compliance with the TDV energy-based compliance metrics; however, the software will allow installing more energy efficiency, demand-responsive measures; battery and storage; and thermal storage systems in exchange for a smaller PV system. Larger PV systems can gain compliance credit for the hourly source energy-based metrics.

Example 9-6 Solar Thermal System

Question:

Does a solar thermal water heating system still qualify for compliance credit in the performance path?

Answer:

Yes, although a solar water heating system cannot serve as a substitution for the prescriptively required PV system, it can still be installed along with PV for optional compliance credit in the performance path. Solar water heating systems are modeled along with the remainder of the water heating and distribution systems and can be used for trading off efficiency measures or installing a smaller PV system. The requirements for solar thermal water heating systems are described in Chapter 4, Water Heating Requirements.

9.4 Community-Shared Solar Electric Generation and Storage Systems

9.4.1 Photovoltaic System Size

§140.1(b)

The 2022 Building Energy Efficiency Standards allow the possibility for the standards requirements for photovoltaics. which would otherwise be installed for the building site, to be offset by community-shared solar electric generation. “Community-shared solar electric generation” means solar electric generation or other renewable technology electric generation that is installed at a different location. Also, the batteries that otherwise would be installed in combination with photovoltaics on the building site to comply with battery storage requirements or to gain performance standards compliance credit potentially could be offset by a community-shared battery storage system that is installed at a different location. Community-shared solar electric generation systems and community-shared battery storage systems possibly can be combined or separate. All of these possibilities are hereinafter referred to as just “community-shared solar electric generation systems.”

For these offsets to become available, entities who wish to serve as administrators of a proposed community-shared solar electric generation system must apply to the CEC for approval, demonstrating that several criteria specified in Section 10-115 of the standards are met. The CEC will carefully consider these applications to determine if they meet these criteria. If approved, CEC-approved compliance software will be modified to enable users to take compliance credit for buildings participating in that CEC-approved community-shared solar electric generation system.

Any entity may apply to serve as administrator of a proposed community-shared solar electric generation system, including, but not limited to, utilities, builders, solar companies, or local governments. The entity will be responsible for ensuring that the criteria for approval are met throughout (at least) a 20-year period for each building that uses shares of the community-shared solar electric generation system to offset the onsite solar electric generation and batteries, which would otherwise be required for the building to comply with the Standards. Throughout that period the administrator will be accountable to builders, building owners, enforcement agencies, the CEC, and other parties who relied on these systems for offset compliance with the standards. Records demonstrating compliance with the criteria must be maintained over that period, with access to those records provided to any entity approved by the Energy Commission.

Entities interested in applying to serve as an administrator of a proposed community-shared solar electric generation system should become thoroughly familiar with the criteria for approval specified in Section 10-115 and contact the CEC Building Standards Office for further discussion and explanation of the criteria as necessary.

To date, only the Sacramento Municipal Utility District (SMUD) has applied to be an administrator for a community-shared solar electric generation system. SMUD's application was approved by the CEC. SMUD's application did not include community-shared storage.

9.4.2 Enforcement Agency

A. The community-shared solar electric generation system must exist and be available for enforcement agency review early in the permitting process and shall not cause delay in the enforcement agency review and approval of the building that will be served by the community-shared solar generation system. All documentation required to demonstrate compliance for the building and the compliance offset from the community-shared solar electric generation system must be completed and submitted to the enforcement agency with the permit application. The enforcement agency must be provided facilitated access to the community-shared solar generation system to verify the validity and accuracy of compliance documentation.

9.4.3 Energy Performance and Minimum Community-Shared PV Size

CEC-approved compliance software must be used to show that the energy performance of the share of the community-shared solar electric generation system that is dedicated to the participating building, generates TDV energy that is equal to or greater than the TDV energy, which would otherwise be required for the building to comply with the standards.

The minimum community-shared solar size dedicated to the building, which is necessary to meet the TDV equivalence of the onsite PV system and the onsite battery storage system that otherwise would be required, is determined by the compliance software. The compliance software will determine a minimum kW size that will be the share of the community solar resource that is required to be dedicated to the building, based on the resource's PV system component performance characteristics, orientation (azimuth and tilt), inverter type, tracking versus fixed systems, climate zone and CEC weather files containing solar availability data.

9.4.4 Participating Building Energy Savings and Bill Reduction Benefits

A specific share of the community-shared solar generation system, determined to comply with the energy performance requirement above, must be dedicated on an ongoing basis to the participating building. The energy savings benefits dedicated to the building shall be provided in one of the following ways:

B. Actual reductions in the energy consumption of the building.

C. Energy reduction credits that will result in virtual reductions in the energy consumption of the building, including, but not limited to, generation credit, solar charge, program charge, and power charge indifference adjustment (PCIA) charge; or

D. Payments to the building that will have an equivalent effect as energy bill reductions that would result from one of the other two options above.

For all three options mentioned above, the reduction in energy bills resulting from the share of the community-shared solar generation system or community-shared battery storage system or both dedicated to the building must be greater than the cost that is charged to the building to obtain that share of the community-shared solar generation system or community-shared battery storage system or both.

9.4.5 Durability, Participation, and Building Opt-Out

A) Durability. The benefits from the specific share of the Community Shared Solar Generation System and/or community shared battery storage system must be provided to each participating building for a period not less than 20 years.

B) Participation. Buildings using community shared solar and/or battery storage systems to comply with Sections 140.0(c), 150.1(a)3, or 170.0(a)3, must participate for at least 20 years, regardless of who owns or occupies the building, unless the building owner fulfills the opt-out requirements. The CEC-approved administrator(s) must require the builder to provide equitable servitude by

a) recording a covenant, or other legally binding method that runs with the land and obligates all owners/tenants to maintain the participation of the building in the community-shared solar and/or community shared battery storage system for at least 20 years or satisfy the opt-out requirements.

B) Compliance Documentation. The administrator must maintain record(s) of the compliance documentation that determined the requirements for the on-site solar electric generation system or battery storage system or both to comply with the standards in effect at the time the builder applied for the original building permit, and that establishes participants' obligations to meet the opt-out requirements. The administrator shall provide a copy of this compliance documentation upon a participating building owner's request, to every new owner of a participating building when the administrator is notified that the title has transferred, and to any participating building owner who requests to opt-out.

C) Building Opt-Out. During the 20-year participation period, the participating building owner has the option to opt out of participation in the community-shared solar electric generation system if the opt-out requirements are met.

a) Before opting out, the building owner must demonstrate that they have installed an on-site solar electric generation system that meets or exceeds the annual TDV energy generation resulting from the on-site PV and battery storage system that would have been required by the Energy Code in effect at the time of the original building permit application for the building. The building owner must also provide documentation from the installer of the on-site solar system or an attestation of the building owner with supporting documentation confirming the installation of the required onsite systems. The building owner is responsible for all costs associated with documentation of the opt-out requirements.

b) The administrator must review opt-out documentation and determine if the installed solar system meets the opt-out requirements. Within 30 days the administrator must provide written confirmation if the building meets the opt-out requirements.

c) All costs and benefits associated with participation in the community-shared solar electric generation system shall cease, and all outstanding balances shall be paid by either party.

d) The administrator (or other approved entity) must not impose any penalty related to a participating building opting out or charge participants for recuperation of unrealized revenue that would have been expected to accrue beyond the end of participation. If the administrator plans to charge any other fees at the time of building opting out, the application for commission approval of the community-shared solar electric generation system shall explain the purpose of those fees.

9.4.6 Additionality

The specific share of the community-shared solar electric generation system must provide the benefits to the participating building that are in no way made available or attributed to any other building or purpose. Renewable Energy Credits (RECs) that are unbundled from the community-shared solar electric generation system do not meet this additionality requirement.

E. The participating building(s) must be served primarily by renewable resources developed specifically for the community-solar electric generation system.

F. Other renewable resources meeting the requirements of Section 10-115(a)4 may be used for each participating building if the building(s) is permitted before the renewable resources developed for the program start operating or after they cease operating.For each renewable resource developed to serve participating buildings, bundled RECs, which satisfy the criteria of Portfolio Content Category 1 of the California Renewable Portfolio Standard regulations, shall be retired and tracked in the Western Renewable Energy Generation Information System (WREGIS) on behalf of program participants to ensure they will not be allocated to or used for any other mandatory or voluntary renewable electricity program requirement or claim.

G. Excess generation from renewable resources may be used to serve other loads but must be isolated from the generation serving participating buildings. This is not considered a violation of Section 10-115(a)5C, the additionality requirement above.

Example 9-8:

Question:

To help entities that might want to apply to the CEC for approval of a community-shared solar energy generation system, please provide examples of each of the three optional ways energy savings benefits could be provided to comply with Section 9.4.3.2.3.

Answer:

Examples would include:

Actual reductions in the energy consumption of the building. These reductions could be accomplished by locating the PV systems for several buildings on a carport on common land in a subdivision, and direct wiring the unique PV panels serving each house to an inverter that is located on the building site. For buildings served by utilities that are subject to compliance with net-energy-metering requirements, the common land that is hosting the PVs on the carport would have to be adjacent to (could be directly across a street) the buildings that are being served by the PV system. All other requirements of Section 10-115 would have to be met.

Utility energy reduction credits that will result in virtual reductions in the energy consumption of the building that is subject to energy bill payments. These reductions could be accomplished for qualifying multifamily dwellings by participation in an approved virtual-net-metering program, which has PVs installed on the multifamily project site, and energy bill credits that reduce the monthly electricity bill of each dwelling unit consistent with net-energy-metering requirements. Alternatively, this could be accomplished through a community-shared solar program administered by a utility (like the Green Tariff Shared Renewables, or GTSR), for which a remote renewable resource is paid for through shares purchased for each building, and energy bill credits are that reduce monthly electricity bills are allocated based on the shares of the buildings, including, but not limited to, generation credit, solar charges, program charges, and nonparticipant charges. All other requirements of Section 10-115 would have to be met.

Payments to the building that will have an equivalent effect as energy bill reductions would result from one of the two options above. This could be accomplished by builders installing PV systems on other properties they own to offset the compliance requirement for onsite PVs on buildings they build. The buildings would pay for a share of the PV systems on the other properties. The builders would be obligated to make an ongoing cash payment back to the buildings for the building share of the electricity generation achieved by the PV systems on the other properties. The share of the ownership of the PV systems on the other properties and the corresponding sharing of the electricity generation achieved by the PV systems on the other properties would not be accounted for through a utility system. The ownership share would not be paid to the utility, and the payment for the share of the electricity generation achieved by the PV systems on the other properties would not be provided through a utility bill. The entire program would be administered by the builder for a 20-year period for each building. All other requirements of Section 10-115 would have to be met.

Example 9-9:

Question:

Could you also explain what the cost requirements are in the last sentence of Section 9.4.3.2.3 that says, "In other words, a building that participates in an approved community solar program, cannot be charged more than the same but nonparticipating building that has no onsite PV system and does not participate in a community-solar program."

Answer:

In a nutshell, regardless of the three options chosen above, it must be cost-effective for the building to participate in a community-shared solar electric generation system program. The participating building will pay for its share of the community renewable resource and receive either energy bill reductions, credits, or cash payments for the electricity generated by the community renewable resource. The value of the reductions, credits, or cash payments to the participating building must exceed its share value of the community renewable resource.

9.5 Battery Storage System

The primary function of the battery storage system is to ~~grid~~ harmonize the onsite PV system with the grid, to ~~bring maximum~~ maximize benefits to the grid, environment, and the occupants.

Grid harmonization: For the purpose of Building Standards, "grid harmonization" is defined as strategies and measures that harmonize customer-owned distributed energy resources assets with the grid to maximize self-utilization of PV array output, and limit grid exports to periods beneficial to the grid and the ratepayer. Grid harmonization is done by charging the battery from the PV system when there is limited electrical load at the building and the cost of electricity is low in midday, and discharging when the cost of electricity is high, usually in the late afternoon and early evening hours.

The battery storage system is available as a compliance credit in the performance compliance method and is a prescriptive requirement for specific nonresidential and hotel/motel as specified in Section 140.10(b). In all cases, the battery storage system must meet all applicable requirements in Joint Appendix JA12 and be self-certified to CEC by the manufacturer as a qualified product.

Coupling a PV system with a battery storage system and appropriate control strategy, described in Section 9.5.2 below, allow reaching specific target time-dependent valuation (TDV) targets and source energy with a smaller PV system than otherwise would have been possible. This strategy is useful and cost-effective for meeting target TDVs that may be required by reach codes, with a smaller and grid-harmonized PV system.

The list of qualified JA12 products can be found at

https://solarequipment.energy.ca.gov/Home/EnergyStorage

9.6 Prescriptive Requirements for Battery Storage System

9.6.1 Battery Storage System Size

§140.10(b) and 170.2(h)

To comply with the prescriptive requirements for specific nonresidential and hotel/motel buildings that are required to have a PV system installed, a battery storage system must also be installed. The minimum qualifying size of the battery storage system is described by the Equations 9-3 and 9-4 below.

Equation 9-3

$kWhbatt = kWPVdc \times B / D^{0.5}$

WHERE:

kWhbatt = Rated Useable Energy Capacity of the battery storage system in kWh

kWPVdc = PV system capacity required by section 9.2 in kWdc

B = Battery energy capacity factor specified in Table 9.6 for the building type

D = Rated single charge-discharge cycle AC to AC (round-trip) efficiency of the battery storage system

Equation 9-4

$kWbatt = kWPVdc \times C$

WHERE:

kWbatt = Power capacity of the battery storage system in kWdc

kWPVdc = PV system capacity required as discussed in section 9.2 in kWdc

C = Battery =power capacity factor specified in Table 9.1 for the building type

Where the building includes more than one of the space types listed in Table 9-6, the total PV system capacity for the building shall be determined by applying Equations 9-3 and 9-4 to each of the listed space types and summing the capacities determined for each.

Table 9-6: Battery Storage Capacity Factors

	Factor B-Energy Capacity	Factor C-Power Capacity
Storage to PV Ratio	Wh/W	W/W
Grocery	1.03	0.26
High Rise Multifamily	1.03	0.26
Office, Financial Institutions, Unleased Tenant Space	1.68	0.42
Retail	1.03	0.26
School	1.87	0.46
Warehouse	0.93	0.23
Auditorium, Convention Center, Hotel/Motel, Library, Medical Office Building/Clinic, Restaurant, Theater	0.93	0.23

Source: California Energy Commission

9.6.2 Exceptions to Battery Storage Requirements

There are five allowable exceptions to the prescriptive PV requirements as listed below.

- Exception 1: No battery storage system is required if the installed PV system size is less than 15 percent of the size determined by Equation 9-1.
- Exception 2: No battery storage system is required in buildings with battery storage system requirements with less than 10 kWh rated capacity.
- Exception 3: For multitenant nonresidential or hotel/motel buildings, the energy capacity and power capacity of the battery storage system must be based on the tenant spaces with more than 5,000 square feet of conditioned floor area. For single-tenant buildings with less than 5,000 square feet of conditioned floor area, no battery storage system is required.

- Exception 4: In Climate Zone 1, no battery storage system is required for offices, schools, and warehouses.

Example 9-10: Battery Exceptions

Question:

I am designing a high-rise multifamily building with 20,000 square feet of conditioned floor area in Climate Zone 3. Is PV or battery storage required for my building?

Answer:

First determine the PV requirement by using Equations 9-1 and 9-2. The PV requirement is the smaller of the results from Equations 9-1 and 9-2.

Using equation 9-1 and Table 9-1. A high-rise multifamily building in Climate Zone 3 has a PV capacity factor of 1.82.

kWPV required = (CFA x A)/1000 = (20,000 x 1.82) / 1000 = 36.4 kW

Using Equation 9-2, the kWPV required = (SARA x 14)/1000 = (650 x 14 /1000 = 9.1 kW

The PV requirement is the smaller of the two numbers, therefore this building is required to have a minimum of 9.1 kW PV system. Now we can determine the battery requirement with equation 9-3.Using equation 9-3 and a battery storage system with 90 percent roundtrip efficiency, kWhbatt = kWPVdc x B / $D^{0.5}$ = 9.1 x 1.03 / (0.9)^0.5 = 9.88 kWh.

Since the required battery storage is less than 10 kWh, this building qualifies for Exception 2 and do not need a battery storage system.

9.6.3 Joint Appendix (JA 12) Requirements

9.6.3.1 Minimum System Performance Requirements

JA12 specifies that the battery storage system must meet or exceed the following performance specifications:

- Usable capacity of at least 5 kWh.
- For prescriptive compliance, single charge-discharge cycle AC to AC (round-trip) efficiency of at least 80 percent
- Energy capacity retention of 70 percent of nameplate capacity after 4,000 cycles covered by a warranty, or 70 percent of nameplate capacity under a 10-year warranty

9.6.3.2 Controls Requirements

Battery storage systems that remain in backup mode indefinitely bring no grid benefits. The JA12 requirements are designed to ensure that the battery storage system remains in an active control mode and prevent the battery storage system from remaining in the backup mode indefinitely. These requirements also enable the battery storage system to receive the latest firmware, software, control strategy, and other important updates.

The following JA12 requirements apply to all control strategies, including Basic Control, Time-of-Use (TOU) Control, and Advanced Demand Response Control, described in Section 9.6.5 below:

1. The battery storage system must have the capability of being remotely programmed to change the charge and discharge periods.
2. During discharge, the battery storage system must be programmed to first meet the electrical load of the dwelling unit(s). If during the discharge period the electrical load of the dwelling unit(s) is less than the maximum discharge rate, the battery storage system shall have the capability to discharge electricity into the grid upon receipt of a demand-flexibility signal from the local utility or a third-party aggregator.
3. The battery storage system must operate in one of the control strategies listed in JA12.2.3.1, JA12.2.3.2, and JA12.2.3.3 except during a power interruption, when it may switch to backup mode. If the battery system switches to backup power mode during a power interruption, upon restoration of power, the battery system shall immediately revert to the previously programmed JA12 control strategy.
4. The battery storage system must perform a system check on the following dates, to ensure the battery is operating in one of the control strategies listed in Section 9.6.5 below:
   a. Within 10 calendar days before the onset of summer TOU schedule
   b. Within 10 calendar days before the onset of winter TOU schedule

If the local utility does not offer TOU rate schedule, the default system check dates should be May 1 and 1 November 1.

9.6.3.3 Controls Strategies

JA12 includes four control strategies that are designed to encourage charging the batteries when electricity prices are low, generally in the middle of the day when solar resources are plentiful and demand is low, and discharge the batteries later in the day when demand is high and solar resources are diminished.

9.6.3.3.1 Basic Control

Designed as a simple control that can be employed as the default control in the absence of TOU or Advanced Demand Flexibility Controls, or where communication between batteries and outside parties are not possible. When combined with an on-site solar PV system, to qualify for the Basic Control, the battery storage system shall be installed in the default operation mode to allow charging only from an on-site PV system when the PV system production is greater than the on-site electrical load. The battery storage system shall discharge only when the PV system production is less than the on-site electrical load.

9.6.3.3.2 Time-of-Use (TOU) Control

This control strategy is designed to take advantage of TOU rates where they are available. This control strategy generally results in a greater energy design rating (EDR) impact than the basic control. When combined with an on-site PV system, to qualify for the TOU Control, the battery storage system shall be installed in the default operation mode to allow charging only from an on-site PV system. The battery storage system shall discharge during the highest priced TOU hours of the day. The operation schedule shall be preprogrammed from factory, updated remotely, or programmed during the installation/commissioning of the system. At a minimum, the system shall be capable of programming three separate seasonal TOU schedules, such as spring, summer, and winter.

9.6.3.3.3 Advanced Demand Flexibility Control

This control strategy is designed to bring the maximum value to the PV system generations by placing the charge/discharge functions of the battery storage system under the control of a utility or a third-party aggregator. This control strategy allows discharging into the gird upon receiving a demand response signal from a grid operator. This option requires robust communication capabilities between the battery storage system and the local utility or the third-party aggregator. When combined with an on-site solar PV system, to qualify for the advanced demand flexibility control, the battery storage system shall be programmed by default as basic control or TOU control as described above. The battery storage control shall meet the demand flexibility control requirements specified in Section 110.12(a). Furthermore, the battery storage system shall have the capability to change the charging and discharging periods in response to signals from the local utility or a third-party aggregator.

9.6.3.3.4 Controls for Separate Battery Storage Systems

When installed separate from (not in combination with) an on-site solar photovoltaic system, including when the building is served by a community solar PV system, to qualify for the compliance credit, the battery storage system shall be programmed by default to start charging from the grid at the onset of lowest priced TOU hours of the day and start discharging at the onset of highest priced TOU hours of the day, or meet all the demand flexibility control requirements specified in Section 110.12(a) and shall have the capability to change the charging and discharging periods in response to signals from the local utility or a third-party aggregator.

9.6.3.3.5 Alternative Control Approved by the Executive Director

The Commission recognizes that there may be other control strategies that bring equal or greater benefits than the ones listed above. Therefore, the executive director may approve alternative control strategies that demonstrate equal or greater benefits to those strategies listed in JA12. To qualify for alternative control, the battery storage system shall be operated in a manner that increases self-utilization of the PV array output, responds to utility rates, responds to demand response signals, minimizes greenhouse gas emissions from buildings, and/or implements other strategies that achieve equal or greater benefits than those specified above. This alternative control option shall be accompanied with clear and easy to implement algorithms for incorporation into the compliance software for compliance credit calculations.

9.6.3.4 Other Requirements

In addition to the requirements above, the battery storage system must also meet the following requirements in JA12:

Safety Requirements: The battery storage system shall be tested in accordance with the applicable requirements given in UL1973 and UL9540. Inverters used with battery storage systems shall be tested in accordance with the applicable requirements in UL1741 and UL1741 Supplement A.

Interconnection and Net-Energy-Metering Requirements: The battery storage system and the associated components, including inverters, shall comply with all applicable requirements specified in Rule 21 and net-energy-metering (NEM) rules as adopted by the California Public Utilities Commission (CPUC).

Electric Rule 21 Tariff provides customers, wishing to install generating or storage facilities on their premises, with access to the electric grid while protecting the safety and reliability of the distribution and transmission systems at the local and system levels.[1]

Enforcement Agency: The local enforcement agency shall verify that all certificates of installations are valid. The battery storage systems shall be verified as a model certified to the CEC as qualified for credit as a battery storage system. In addition, the enforcement agency shall verify that the battery storage system is programmed and operational with one of the controls listed in Section 9.5.2 above. The programmed control strategy at system final inspection and commissioning shall be the strategy that was used in the certificate of compliance.

Example 9-11: Battery Storage Credit

Question:

Can you get compliance credit for battery storage and how to comply with them?

1 "Rule 21 Interconnection," California Public Utilities Commission, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/rule-21-interconnection.

Answer:

Battery storage is a prescriptive requirement for certain nonresidential building types. (See Table 9-6.) Additional compliance credit is available under the performance path allows a compliance credit for a battery storage system larger than the prescriptive requirement. It can be used for compliance tradeoff for a smaller PV system and source energy.

The manufacturers must self-certify to CEC that the battery storage systems meet the requirements of JA12. JA12 lists minimum performance requirements, communication requirements, control requirements, safety requirements, and interconnection requirements, among others, that must be complied with and certified to the CEC. The self-certification form may be downloaded from the Commission's website.

Example 9-12: Battery Storage Credit

Question:

When batteries are used there is a loss of electricity associated with the roundtrip charge and discharge resulting in fewer generated kWh. Why does the CEC require a battery storage system that is coupled with a PV system if there is a loss of energy?

Answer:

Battery storage systems store the PV generated electricity in the middle of the day when the solar resources are generally plentiful and electricity prices are low. The systems discharge the stored electricity later in the day, during the peak hours when solar resources are diminished and electricity prices are high. Battery storage systems have a roundtrip charge and discharge loss of 5 to 15 percent, depending on the type of battery technology and the inverter efficiencies. The electricity price differential between the middle of the day and the peak hours is greater than the battery charge and discharge losses. This means that even with the relatively small loss of electricity, it is still cost-effective for a consumer to store electricity generated onsite around midday and use it later on instead of purchasing additional electricity from the grid.

To calculate the performance of a battery storage system coupled with a PV system, the CEC's compliance software on hourly basis accounts for the PV generation, losses, storage capacity remaining, charge and discharge rates, cost of electricity, house loads, and hourly exports. Similar calculations are also performed to calculate the benefits of storage for CO2 emissions.

Not any battery storage system is eligible for compliance credit; it must comply with the requirements of Reference Joint Appendix 12 (JA12). The requirements ensure that the battery storage system remains in a dynamic mode that allows residents to take advantage of variable electricity costs associated with charge and discharge periods throughout the day. Static batteries that remain mostly in backup mode have little to no value to the building owner, the grid, or the environment.

Example 9-13: Battery Storage TOU Schedule

Question:

How will control requirement be enforced for customers that are not on a TOU schedule? How about customers on TOU rate but wants to be in basic control?

Answer:

If the local utility does not have TOU schedule, to comply with JA12.2.3 the battery storage system should perform a system check on May 1 and November 1 by default. A customer can set the control strategy to Basic Control, regardless of whether a TOU rate is available for the customer; however, this strategy will reduce the benefits of the battery storage for both the customer and the grid and, therefore, is not recommended.

9.7 Performance Approach Compliance for Battery Storage System

9.7.1 Energy Budget Calculation

The computer performance approach allows for the modeling of the battery storage system performance by taking into account battery system size, climate, building type, and battery efficiency. The standard design battery storage system size is determined by the prescriptive PV size required for proposed design building, regardless of the actual fuel type of the proposed design building. The performance method allows for battery storage system, control strategies and other demand-response measures.

9.7.2 Exceptions to Battery Storage Requirements

The five allowable exceptions to the prescriptive PV requirements listed in Section 9.6.2. can also be used under the performance approach. User must select the appropriate exception in the software and provide documentation to the building department with the building permit application.

9.7.3 Additional Requirements

The installed battery storage system must meet the applicable requirements as specified in JA12, above.

9.8 Solar-Ready Overview

§110.10

This chapter of the nonresidential compliance manual addresses solar-ready requirements for hotels/motels, nonresidential, and high-rise multifamily buildings. These requirements are in §110.10 and §141.0 and are mandatory for newly constructed buildings and additions where the total roof area is increased by at least 2,000 square feet.

The solar-ready requirement is implemented when designing the building rooftop and associated equipment. The intent is to reserve a penetration-free and shade-free portion of the roof for the potential future installation of a solar energy system. There are no requirements to install panels, conduit, piping, or mounting hardware.

9.8.1 Overview

The solar-ready provisions are mandatory; “trade-offs” are not allowed. There are exceptions to the “solar zone” requirements, and these are described in the corresponding sections of this chapter. Because solar ready is mandatory, the NRCC-SRA-E compliance form must be submitted with the building permit application, even when using an allowable solar zone exception.

9.8.2 Covered Occupancies

§110.10(a)

The nonresidential solar-ready requirements apply to:

- Hotel/motel occupancies with 10 stories or fewer.
- All other nonresidential buildings with three stories or fewer.
- See Example 9-15

Mixed-Occupancy Buildings: The Energy Standards apply to mixed-occupancy buildings. Buildings with nonresidential space on the ground floor and multifamily residential floors above are common examples.

9.8.3 Solar Zone

§110.10(b)

The solar zone is a suitable place where solar panels can be installed at a future date if the owner chooses to do so. A solar zone area is designed with no penetrations, obstructions, or significant shade. The solar zone must comply with the access, pathway, smoke ventilation, and spacing requirements in Title 24, Part 9. Requirements from the other parts of Title 24 and those adopted by a local jurisdiction should also be incorporated in the solar zone design.

The solar zone can be located at any of the following locations:

- Roof of building
- Overhang of the building
- Covered parking installed with the building project
- Roof of another structure located within 250 feet (75 meters) of the primary building
- Overhang of another structure within 250 feet (75 meters) of the primary building

Other structures include, but are not limited to, trellises, arbors, patio covers, carports, gazebos, and similar accessory structures.

Multifamily Buildings: Solar-ready requirements for low-rise and high-rise multifamily buildings are in Chapter 11 of the Nonresidential Compliance Manual. In the 2022 Energy Standards, the solar zone requirements for low-rise multifamily buildings are grouped with high-rise multifamily, hotel/motel and nonresidential in §110.10(b)1B.

9.8.4 Solar Zone Minimum Area and Exceptions

§110.10(b)1

Total Area: The solar zone must have a total area of at least 15 percent of the total roof area, after subtracting any skylights. See Example 9-16.

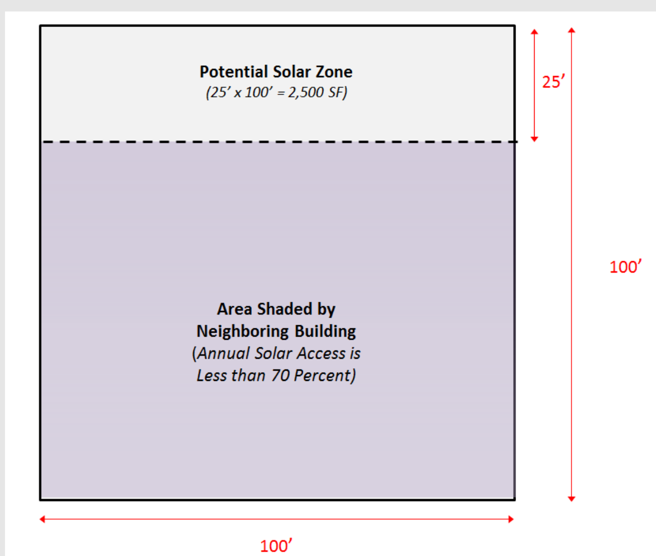
Multiple areas: The solar zone may be composed of multiple subareas if they meet the following minimum size specifications:

1. Each subarea dimension must be at least 5 feet.
2. If the total roof area is equal to or less than 10,000 square feet, each subarea must be at least 80 square feet.
3. If the total roof area is greater than 10,000 square feet, each subarea must be at least 160 square feet.

Example 9-14:

Question:

A roof with no skylights has an area of 10,000 sq. ft. A neighboring building shades the roof, so 7,500 sq. ft of the roof has less than 70 percent annual solar access. How big does the solar zone have to be?



Answer:

If the entire roof had an annual solar access of 70 percent or greater, the minimum solar zone would be 1,500 sq. ft, or 15 percent of the total roof area (10,000 sq. ft.). However, since the potential solar zone is 2,500 sq. ft, the minimum solar zone can be reduced to half the area of the potential solar zone, or 1,250 sq. ft.

Example 9-15:

Question:

The total roof area is less than 10,000 sq. ft., but the potential solar zone is less than the minimum size requirements for any subarea (less than 80 sq. ft. or narrower than 5 feet in the smallest dimension). Does the building still need to comply with the solar-ready requirements?

Answer:

No. If half the potential solar zone is less than 80 sq. ft. (if roof is less than or equal to 10,000 sq. ft) or 160 sq. ft. (if roof is greater than 10,000 sq. ft), then the building does not need to comply with the solar zone requirements.

Example 9-16:

Question:

A portion of an office building will have six stories, and a portion of the building will have two stories. Is the new building subject to the solar zone requirements?

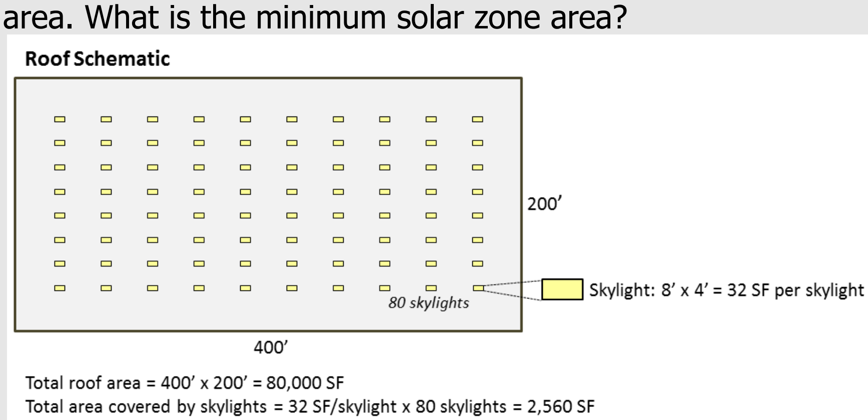
Answer:

No, the solar-ready requirements do not apply to office buildings that have more than three stories. The solar-ready requirements apply only to hotel/motel occupancies and high-rise multifamily buildings with 10 or fewer stories and all other nonresidential buildings with 3 or fewer stories.

Example 9-17:

Question:

A new warehouse has a total roof area of 80,000 sq. ft. Skylights cover 2,560 sq. ft. of the total roof area. What is the minimum solar zone area?



Answer:

The minimum solar zone area would be 11,616 sq. ft

$$Minimum\ Solar\ Zone\ Area = 15\%\ x\ (Total\ Roof\ Area - Area\ Covered\ by\ Skylights)$$

$$\mathbf{11,616\ sq.ft} = 15\%\ x\ (80{,}000\ sq.ft - 2{,}560\ sq.ft)$$

Example 9--18:

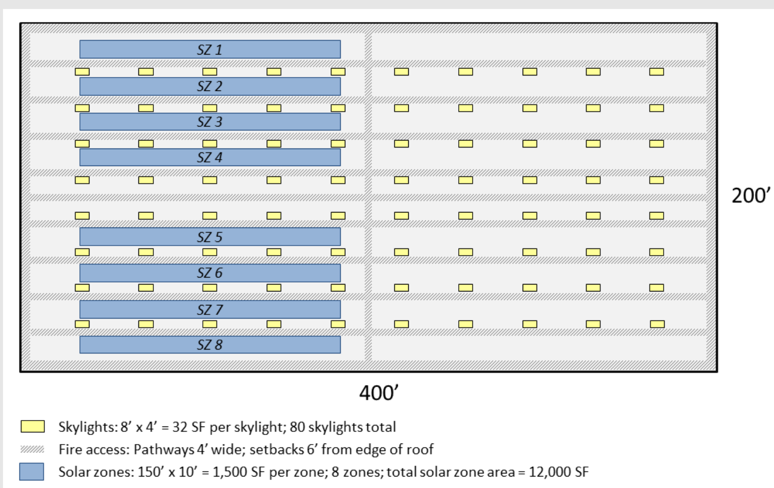
Question:

Does the solar zone have to be one contiguous area?

Answer:

No, the solar zone does not have to be one contiguous area. The total solar zone can be composed of multiple smaller areas. A subarea cannot be narrower than 5 feet in any dimension. If the total roof area is 10,000 sq. ft or less, each subarea must be at least 80 sq. ft. If the total roof area is greater than 10,000 sq. ft, each subarea must be at least 160 sq. ft.

The image below illustrates a solar zone layout that is composed of eight smaller subareas. The sum of all the smaller areas must equal the minimum total solar zone area. In this case, the sum of all areas must be at least 11,616 sq. ft. The solar zones must also comply with fire code requirements, including, but not limited to, setback and pathway requirements. Current fire code requirements can be found in Title 24 Part 2 § 3111, Title 24 Part 2.5 §R331, and Title 24 Part 9 § 903.3.



9.8.5 Solar Zone Exceptions

There are five exceptions to the solar zone area requirement described in §110.10(b)1B. Some exceptions are limited to certain buildings, as noted in the exception details below. Submit an NRCC-SRA-E, the "Solar Ready Areas" certificate of compliance to the enforcement agency for all building projects subject to solar ready, even if using a solar zone exception.

Exception 3 allows a reduced-size solar zone when solar access is limited by certain circumstances.

Exceptions 1, 2, and 4 allow alternate efficiency measures instead of a solar zone, so the requirements for zone shading, orientation, and design load; interconnection pathway; and owner documentation do not apply either. Any installations must be inspected and verified prior to final approval by the enforcement agency.

Exception 1: A compliant solar electric system is permanently installed on high-rise multifamily, hotel/motel, and nonresidential buildings. The system must have a nameplate direct current (DC) power rating of no less than 1 watt per sq. ft of roof area. The nameplate rating must be measured under standard test conditions. See Example 9-6. To verify compliance with this exception, submit NRCI-SPV-01-E Certificate of Installation: Solar Photovoltaic System.

Exception 2: A solar hot water system (SWH) is permanently installed on high-rise multifamily, hotel/motel, and nonresidential buildings. The SWH system must comply with §150.1(c)8Biii, the prescriptive solar requirements for a system serving multiple dwelling units. To verify compliance with this exception, submit NRCI-STH-01-E Certificate of Installation: Solar Water Heating System.

Exception 3: Reduce the solar zone area when the roof is shaded by objects that are not part of the building project, and therefore beyond the designer's control. The designated solar zone may be reduced to ≥ 50 percent of the potential solar zone area when solar access is limited as described below. When the "potential" solar zone is smaller than the 250 sq. ft minimum, the solar zone can be reduced to half the area of the potential solar zone. The reduced-size solar zone is called the "designated" solar zone.

Exception for Reduced Solar Zone

Step 1: Determine the annual solar access: For the solar-ready requirements, solar access is the ratio of solar insolation including shading to the solar insolation without shading. Annual solar access is most easily determined using specialized software.

$$Solar\ Access = \frac{Solar\ Insolation\ Including\ Shading}{Solar\ Insolation\ Without\ Shading}$$

Solar access does not take into account shading from objects that are included in the building project because the designer has control of potential obstructions. Objects that are not part of the building project cannot be moved or modified as part of the project and include existing buildings, telephone poles, communication towers, trees, or other objects. Objects that are considered part of the building project are objects constructed as part of the building project and include the building itself, its HVAC equipment, outdoor lights, landscape features and other similar objects.

First, evaluate whether there are any objects outside the building project that will shade the rooftop (or other prospective solar zone areas such as overhangs or parking shade structures). If an existing object is located north of all potential solar zones, the object will not shade the solar zone. Similarly, if the horizontal distance ("D") from the object to the solar zone is at least two times the height difference ("H") between the highest point of the object and the horizontal projection of the nearest point of the solar zone, then the object will not shade the solar zone. (See Figure 9-2.)

Step 2: Determine the potential solar zone area: On low-sloped roofs, the potential solar zone is the area where annual solar access is ≥ 70 percent.

On steep-sloped roofs the potential solar zone is the area where the annual solar access is

≥ 70 percent on the portion oriented between 90 and 300 degrees of true north.

A "demand-responsive control" is defined in §100.1 as an "automatic control capable of receiving and automatically responding to a demand response signal." The technical specifications for compliant demand responsive control thermostats are detailed in JA5.

In addition to the demand-responsive thermostats, choose Option A or Option B (below).

Each dwelling unit must have one of the following four measures (1 – 4):

a) Install a dishwasher that meets or exceeds the ENERGY STAR® program requirements with either a refrigerator that meets or exceeds the ENERGY STAR program requirements or a whole-house fan driven by an electronically commutated motor.

b) Install a home automation system that complies with §110.12(a) and capable of, at a minimum, controlling the appliances and lighting of the dwelling and responding to demand-response signals.

c) Install alternative plumbing piping to permit the discharge from the clothes washer and all showers and bathtubs to be used for an irrigation system. It must comply with the California Plumbing Code and local ordinances.

d) Install a rainwater catchment system that uses rainwater flowing from at least 65 percent of the available roof area. It must comply with the California Plumbing Code and local ordinances.

Meet the Title 24 Part 11, Section A4, 106.8.2 requirements for electric vehicle charging spaces.

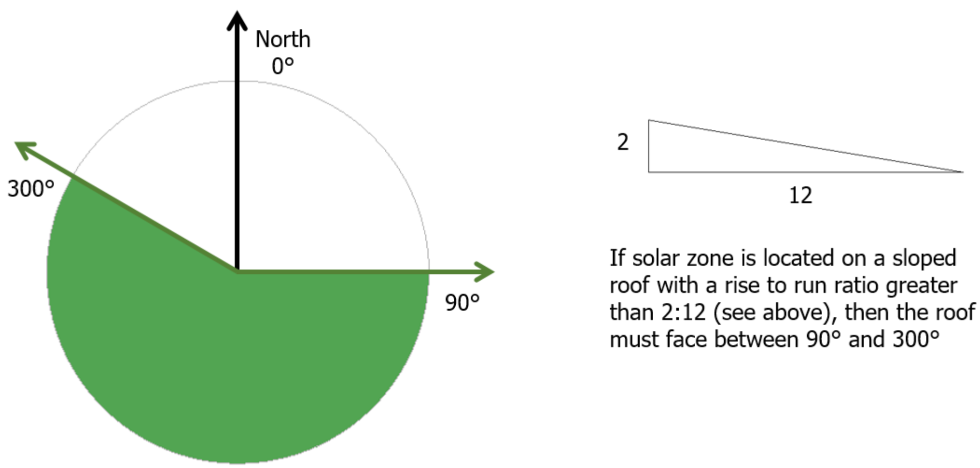
Exception 5: Applies to multifamily, hotel/motel, and nonresidential buildings. If the roof is designed and approved to be a heliport, or used for vehicular traffic or parking, no solar zone is required. Therefore, interconnection pathway and documentation requirements do not apply.

9.8.5.1 Solar Zone Azimuth

150.1(c)8Biii

All sections of the solar zone on steep-sloped roofs (rise-to-run ratio greater than 2:12, or 10 degrees) must be oriented between azimuths of 90 degrees and 300 degrees of true north. This range of azimuths ensures a reasonable solar exposure if a solar energy system is installed in the future. On a low-sloped roof (rise-to-run ratio equal to or less than 2:12, or 10 degrees), the azimuth requirement does not apply.

Figure 9-1: Azimuth of Roof If Solar Zone Is Located on Steep-Sloped Roof



Source: California Energy Commission

9.8.5.2 Solar Zone Shading

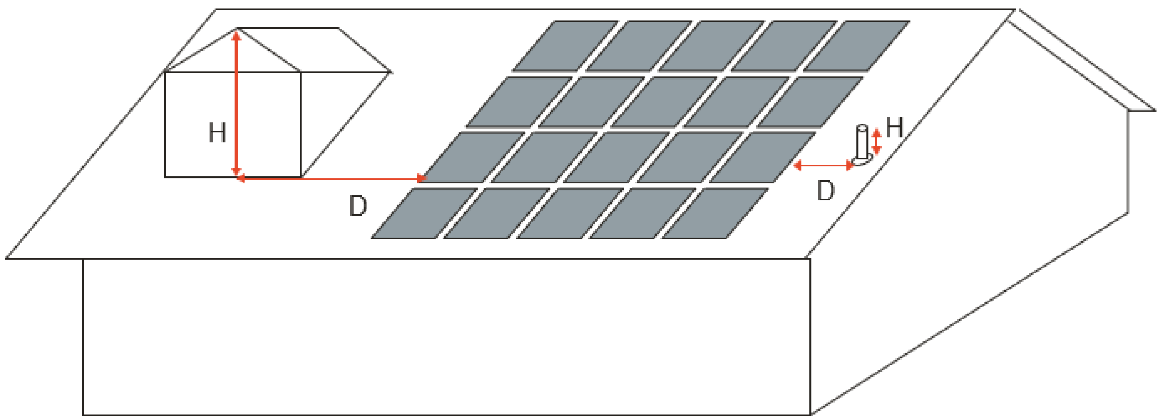
§110.10(b)3

Obstructions such as vents, chimneys, architectural features, or roof-mounted equipment cannot be located in the solar zone. This requirement ensures the solar zone remains clear and open for the future installation of a solar energy system.

Any obstruction located on the roof or any other part of the building that projects above the solar zone must be located at a sufficient horizontal distance away from the solar zone such that the obstruction will not shade the solar zone. Equation 9-5 and Figure 9.2 describe the allowable distance between any obstruction and the solar zone. For each obstruction, the horizontal distance ("D") from the obstruction to the solar zone has to be at least two times the height difference ("H") between the highest point of the obstruction and the horizontal projection of the nearest point of the solar zone.

Figure 9-2: Schematic of Allowable Setback for Rooftop Obstructions

Equation 9-5: $D \geq 2H$



Source: California Energy Commission

Any obstruction that is not located on the roof or another part of the building, such as landscaping or neighboring building, or is oriented north of all points of the solar zone is not subject to the shading requirement.

9.8.5.3 Solar Zone Structural Design Loads

§110.10(b)4

The structural design load requirements apply if any portion of the solar zone is located on the roof of the building. For the areas of the roof designated as the solar zone, the structural design loads for roof dead load and roof live load shall be clearly indicated on the construction documents. This is required so that the structural loads are known if a solar energy system is installed in the future.

The Energy Standards do not require estimating the loads of possible future solar equipment.

9.8.5.4 Interconnection Pathways

§110.10(c)

All buildings that include a solar zone must also include a plan for connecting a PV or SWH system to the electrical or plumbing system of the building. The construction documents must indicate:

1. A location for inverters and metering equipment for future solar electric systems. The allocated space should be appropriately sized for a PV system that could cover the entire solar zone.

2. A pathway for routing conduit from the solar zone to the point of interconnection with the electrical service. The design drawings must show where the conduit would be installed if a system were installed at a future date. There is no requirement to install conduit.
3. A pathway for routing plumbing from the solar zone to the water-heating system connection. The design drawings must show where the plumbing would be installed if a SWH system were installed at a future date. There is no requirement to install piping.

This requirement is not applicable if compliance is achieved by using Exceptions 1, 2, or 4 in lieu of a designated solar zone.

9.8.5.5 Documentation for the Building Occupant

§110.10(d)

A copy of the construction documents that show the solar zone, the structural design loads, and the interconnection pathways must be provided to the building occupant. The building occupant must also receive a copy of compliance document NRCC-SRA-E. The document copies are required so that the solar-ready information is available if the occupant decides to install a solar energy system in the future. This requirement is not applicable if compliance is achieved by using Exceptions 1, 2, or 4 in lieu of a designated solar zone.

Example 9-19:

Question:

An office building has a total roof area of 5,000 sq. ft. The total roof area covered by skylights is 200 sq. ft. A solar PV system with a DC power rating (measured under standard test conditions) of 4 kilowatts (kW) will be installed. The collection panels for the 4 kW system will cover 400 sq. ft. Does the building have to have to include a solar zone in addition to the installed solar PV system?

Answer:

Yes. To be exempt from the solar zone requirement, the solar PV system must have a power rating equal to 1 watt for every sq. ft of roof area, or in this case 5 kW (see equation below).

$$Minimum\ PV\ System\ Power\ Rating\ = Total\ Roof\ Area\ x\ 1\ Watt\ per\ sq.ft$$

$$\mathbf{5,000W} = \ 5000\ sq.ft\ \times \frac{1W}{sq}.ft$$

The minimum solar zone for this building is 720 sq. ft (See calculation below.) The 400 sq. ft on which the solar PV system is installed does count toward the minimum solar zone area, so an additional 320 sq. ft would need to be allocated to complete the minimum solar zone requirement.

$$Minimum\ Solar\ Zone\ Area = 15\%\ x\ (Total\ Roof\ Area - Area\ Covered\ by\ Skylights)$$

$$\mathbf{720\ SF} = 15\%\ x\ (5{,}000\ sq.ft \times 200\ sq.ft)$$

9.8.6 Additions

§141.0(a)

The solar-ready requirements for additions are covered by the Energy Standards in §141.0(a). Additions do not need to comply with the solar-ready requirements unless the addition increases the roof area by more than 2,000 sq. ft. (200 sq. meters).

9.8.7 California Fire Code Solar Access Requirements

Following regulations established by the Office of the State Fire Marshal, the 2016 version of Parts 2, 2.5, and 9 of Title 24 include requirements for installing rooftop solar photovoltaic systems. These regulations cover the marking and location of DC conductors and access and pathways for photovoltaic systems. They apply to residential and nonresidential buildings regulated by Title 24 of the California Building Standards Codes. Provided below is a summary of the fire code requirements for nonresidential buildings.

PV arrays shall not have dimensions in either axis that exceed 150 ft. Nonresidential buildings shall provide a 6-foot-wide access perimeter around the edges of the roof. Smoke ventilation options must exist between array installations and next to skylights or smoke and heat vents. Builders shall refer directly to the relevant sections of Title 24 (Part 2: Section 3111, Part 2.5 Section R331, and Part 9 Section 903.3) for detailed requirements.

9.8.8 Compliance and Enforcement

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the documents and procedures for documenting compliance with the solar-ready requirements of the Energy Standards. The following discussion pertains to the designer preparing construction and compliance documents and to enforcement agency plan checkers who are examining those documents for compliance with the Energy Standards.

There are three documents to demonstrate compliance with the nonresidential solar ready requirements. Each document is briefly described below.

- NRCC-SRA-E: Certificate of Compliance: Nonresidential Solar Ready Areas
    - This document is required for every project where the solar-ready requirements apply: newly constructed hotel/motel buildings with 10 or fewer stories, high-rise multifamily buildings with 10 or fewer stories, all other newly constructed nonresidential buildings with 3 or fewer stories, and additions to the previously mentioned buildings that increase the roof area by more than 2,000 sq. ft. This form is required for all covered occupancies, including projects that use any of the solar zone exceptions.

- NRCI-SPV-01-E: Certificate of Installation — Solar Photovoltaic System
    - This document is required when using solar zone Exception 1 to achieve compliance.
- NRCI-STH-01-E: Certificate of Installation — Solar Water Heating System
    - This document is required when using solar zone Exception 2 to achieve compliance.

Table of Contents

10 Covered Processes

10.1 Introduction

This chapter of the Nonresidential Compliance Manual addresses covered processes for the *2022 Building Energy Efficiency Standards* (Energy Codes) (§120.6 and §140.9).

10.1.1 Organization and Content

This chapter is organized as follows:

- 10.1 — Introduction to Covered Processes
- 10.2 — Enclosed Parking Garages
- 10.3 — Commercial Kitchens
- 10.4 — Computer Rooms
- 10.5 — Commercial Refrigeration
- 10.6 — Refrigerated Warehouses
- 10.7 — Laboratory Exhaust
- 10.8 — Compressed Air Systems
- 10.9 — Process Boilers
- 10.10 — Elevator Lighting and Ventilation Controls
- 10.11 — Escalators and Moving Walkways Speed Controls
- 10.12 — Controlled Environment Horticulture
- 10.13 — Steam Traps

10.1.2 Compliance Forms

Compliance documentation includes the certificates of compliance, reports, and other information that are submitted to the enforcement agency with an application for a building permit. Compliance documentation also includes documentation completed by the installing contractor, engineer/architect of record, or owner's agent to verify that certain systems and equipment have been correctly installed and commissioned.

Under the prescriptive compliance approach, the project designer is responsible for completing the Process Compliance Forms & Worksheets. The project designer is required to complete all applicable sections of the NRCC-PRC-E. This form is required on plans for all submittals with covered processes. For the performance compliance approach this form will automatically be completed by the approved computer compliance program.

10.1.3 What Is New for the 2022 California Energy Code?

Significant changes for covered process in the 2022 update to the Energy Codes include both new processing loads being covered as well as additional requirements being applied to process loads that were covered by the energy code previously.

Newly covered process loads include:

- Controlled environment horticulture (mandatory measures).
  - Electric lighting for growing plants now must have high photosynthetic photon efficacy (PPE), which is spectrum-efficient for growing plants, and must have dimming and timeclock controls.
  - Dehumidifiers must meet federal dehumidifier standards or recover at least 75 percent of the heat used for reheating.
  - Conditioned greenhouses must have at least two glazing layers.
- Steam traps (mandatory measures).
  - Steam trap monitoring system which provides status updates of steam trap fault detection sensors.
  - Steam traps must have an integral strainer and blow-off valves, or a strainer and blow-off valve must be installed within 3 feet upstream of the steam trap.
- Compressed air systems (mandatory measures).
  - Base-compressed air-system requirements on total horsepower of compressors connected to compressed air piping.
  - Energy and air demand monitoring systems capable of measuring and logging pressure, compressor power and compressor airflow of the compressed air systems.
  - Leak testing requirements for compressed air piping.
  - Compressed air system pipe sizing requirements to minimize frictional losses in the distribution system.
- Computer room (prescriptive measures).
  - Require minimum efficiencies for alternating current uninterruptible power supplies.
- Transcritical carbon dioxide (CO_2) refrigeration systems in refrigerated warehouses (mandatory)
  - Minimum condensing temperature
  - Transcritical gas coolers — sizing requirements, minimum efficiency and air-cooled gas coolers prohibited in some climate zones

- Transcritical CO_2 refrigeration systems in commercial refrigeration (mandatory)
    - Minimum condensing temperature
    - Transcritical gas coolers — sizing requirements, minimum efficiency and air-cooled gas coolers prohibited in some climate zones
- Automatic door closers in refrigerated warehouses

Revisions to covered process loads previously regulated under the Energy Code:

- Computer room (mandatory measures).
    - Prohibit reheating and simultaneous heating and cooling.
    - Humidification shall be adiabatic.
    - Unitary air conditioners and chilled water fan systems shall be designed to vary the airflow rate as a function of actual load.
- Computer room (prescriptive measures).
    - Define supply air temperatures for air and water economizers.
    - For air economizers and water economizers, revise ambient air temperatures when full economizing occurs.
    - Require air containment for computer rooms with information technology equipment (ITE) of 10 kW or more.

10.2 Enclosed Parking Garages

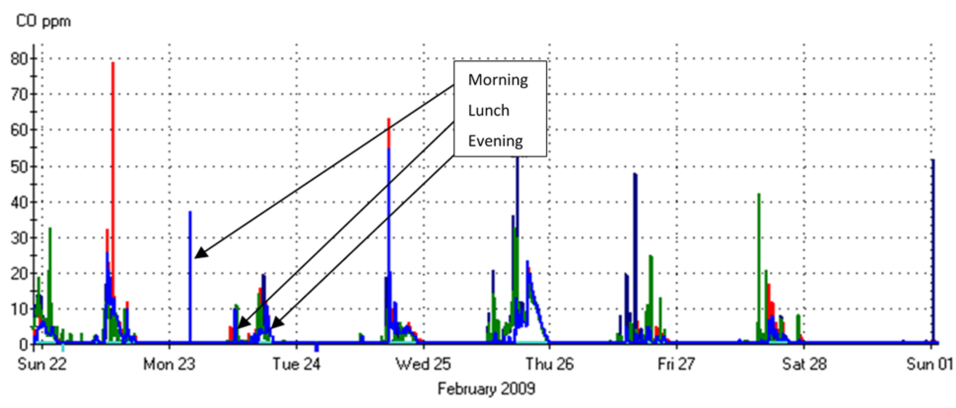
10.2.1 Overview

Garage exhaust systems are sized to dilute the auto exhaust at peak conditions to an acceptable concentration for human health and safety. Energy management control system (EMCS) monitoring of garage carbon monoxide (CO) concentrations show that in a typical enclosed garage, there are three periods of concern:

- In the morning when cars enter the garage
- During the lunch break when cars leave and reenter
- At the end of the day when cars leave

This mandatory measure requires modulating ventilation airflow in large, enclosed parking garages based on pollutant concentrations. By modulating airflow based on need rather than running constant volume, the system will save energy and maintain a safe environment.

Figure 10-1: Garage CO Trends



Source: California Energy Commission

10.2.2 Mandatory Measures

For garage exhaust systems with a total design exhaust rate ≥10,000 cubic feet per minute (cfm), §120.6(c) requires automatic controls to modulate airflow to ≤50% of design based on measurements of the contaminant concentrations. This requirement includes:

a. Minimum fan power reduction of the exhaust fan energy to ≤ 30% of design wattage at 50 percent of design flow. A two-speed or variable-speed motor can be used to meet this requirement.

b. CO concentration measured with at least one sensor per 5,000 ft^2 with each sensor located where the highest concentrations of CO are expected.

c. CO concentration of 25 ppm or less as control set point at all times.

d. A minimum ventilation of 0.15 cfm/ft^2 when the garage is "occupied."

e. The garage maintained at a neutral or negative pressure with respect to adjacent occupiable areas when the garage is scheduled to be occupied.

f. CO sensors certified to the minimum performance requirements listed under §120.6(c) of the Energy Codes.

g. Acceptance testing of the ventilation system per NA7.12.

10.2.2.1 Minimum Fan Power Reduction

§120.6(c)2

Where required, the fan control must be designed to provide ≤30% of the design fan wattage at 50 percent of the fan flow. This can be achieved by either a two-speed motor or a variable-speed drive.

10.2.2.2 CO Sensor Number and Location

§120.6(c)3

CO sensors (or sampling points) must be located so that each sensor serves an area no more than 5,000 ft^2. Furthermore, the standard requires a minimum of two sensors per "*proximity zone*." *Proximity zones* are defined as areas that are separated by obstructions including floors or walls.

The typical design for garage exhaust is to have the exhaust pickups located on the other side of the parking areas from the source of makeup air. The ventilation air sweeps across the parking areas and toward the exhaust drops. Good practice dictates that you would locate sensors close to the exhaust registers or in dead zones where air is not between the supply and exhaust. Floors and rooms separated by walls should be treated as separate proximity zones.

10.2.2.3 CO Sensor Minimum Requirements

§120.6(c)7

To comply, each sensor must meet all of the following requirements:

a. Certified by the manufacturer to:
    1. Accuracy of +/- 5%.
    2. 5% or less drift per year.
    3. Require calibration no more than once per year.
b. Be factory-calibrated
c. The control system must monitor for sensor failure. If sensor failure is detected, the control system must reset to design ventilation rates and transmit an alarm to the facility operators. At a minimum, the following must be monitored:
    1. If any sensor has not been calibrated according to the manufacturer’s recommendations within the specified calibration period, the sensor has failed.
    2. During unoccupied periods, the system compares the readings of all sensors. For example, if any sensor is more than 15 ppm above or below the average of all sensors for longer than four hours, the sensor has failed.
    3. During occupied periods, the system compares the readings of sensors in the same proximity zone. For example, if the 30-minute rolling average for any sensor in a proximity zone is more than 15 ppm above or below the 30-minute rolling average for other sensor(s) in that proximity zone, the sensor has failed.

10.2.3 Prescriptive Measures

There are no prescriptive measures for enclosed garage exhaust.

10.2.4 Additions and Alterations

There are no separate requirements for additions and alterations.

10.3 Commercial Kitchens

10.3.1 Overview

There are four energy-saving measures associated with commercial kitchen ventilation. These four prescriptive measures address:

1. Direct replacement of exhaust air limitations.
2. Type I exhaust hood airflow limitations.
3. Makeup and transfer air requirements.
4. Commercial kitchen system efficiency options.

10.3.2 Mandatory Measures

There are no mandatory measures specific to commercial kitchens. Installed appliances and equipment must meet the mandatory requirements of §110.1 and §110.2, respectively.

10.3.3 Prescriptive Measures

10.3.3.1 Kitchen Exhaust Systems

§140.9(b)1

This section addresses kitchen exhaust systems. There are two requirements for kitchen exhaust:

1. A limitation on use of short-circuit hoods §140.9(b)1A
2. Maximum exhaust ratings for Type I kitchen hoods §140.9(b)1B

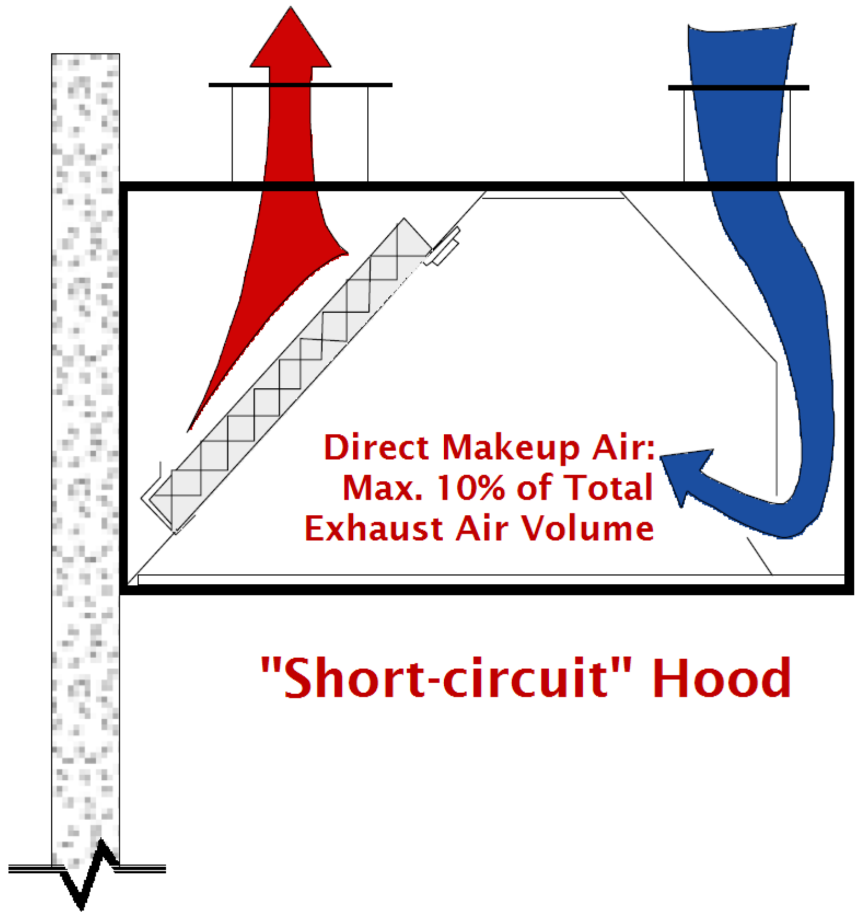
A. Limitation of Short-Circuit Hoods

§140.9(b)1A

Short-circuit hoods are limited to ≤10% replacement air as a percentage of hood exhaust airflow rate. The reasons for this include the following:

Studies by Pacific Gas and Electric (PG&E), the American Gas Association (AGA), and the California Energy Commission (CEC) have shown that in short-circuit hoods, direct supply greater than 10 percent of hood exhaust significantly reduces capture and containment. This reduces the extraction of cooking heat and smoke from the kitchen, forcing facilities to increase the hood exhaust rate. This reduction results in higher consumption of energy and conditioned makeup air.

Figure 10-2: Short-Circuit Hood



10.3.3.1 Maximum Exhaust Ratings for Type I Kitchen Hoods

§140.9(b)1B

The Energy Codes also limit the amount of exhaust for Type I kitchen hoods based on Table 140.9-A (Table 10-1 below), when the total exhaust airflow for Type I and II hoods are greater than 5,000 cfm. Similar to the description regarding short-circuit hoods, excessive exhaust rates for Type I kitchen hoods increases energy consumption and increases energy use for conditioning of the makeup air.

There are two exceptions for this requirement:

1. Exception 1 to §140.9(b)1B, where ≥75% of the total Type I and II exhaust makeup air is transfer air that would otherwise have been exhausted. This exception could be used when you have a large dining area adjacent to the kitchen, which would be exhausting air for ventilation even if the hoods were not running. The exception is satisfied if the air that would otherwise have been exhausted from the dining area (to meet ventilation requirements), is greater than 75 percent of the hood exhaust rate, and is transferred to the kitchen for use as hood makeup air.

2. Exception 2 to §140.9(b)1B: Existing hoods that are not being replaced as part of an addition or alteration.

The values in Table 140.9-A are based on the type of hood (left column) and the rating of the equipment that it serves (light-duty through extra-heavy-duty). The values in this table are typically less than the minimum airflow rates for hoods that are not Underwriter Laboratories (UL) specification-listed products. These values are supported by ASHRAE research for use with UL-listed hoods. (For more detail see ASHRAE research project report RP-1202.) To comply with this requirement, the facility will likely have to use listed hoods. The threshold of 5,000 cfm of total exhaust was included in the Energy Codes to exempt small restaurants.

The definitions for the types of hoods and the duty of cooking equipment are provided in ASHRAE Standard 154-2011.

Table 10-1: Maximum Net Exhaust Flow Rate, CFM per Linear Foot of Hood Length

Type of Hood	Light-Duty Equipment	Medium-Duty Equipment	Heavy-Duty Equipment	Extra-Heavy-Duty Equipment
Wall-mounted Canopy	140	210	280	385
Single Island	280	350	420	490
Double Island	175	210	280	385
Eyebrow	175	175	Not Allowed	Not Allowed
Back shelf/Pass-over	210	210	280	Not Allowed

Energy Codes Table 140.9-A

10.3.3.2 Kitchen Ventilation

§140.9(b)2

This section covers two requirements:

1. Limitations to the amount of mechanically heated or cooled airflow for kitchen hood makeup air §140.9(b)2A
2. Additional efficiency measures for large kitchens §140.9(b)2B.

For these requirements, it is important to understand the definition of mechanical cooling and mechanical heating, which the Energy Codes define as the following:

a. ***Mechanical cooling*** is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy from depletable sources to directly condition the space. In nonresidential, and hotel/motel buildings, cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling.

b. ***Mechanical heating*** is raising the temperature within a space using electric resistance heaters, fossil-fuel burners, heat pumps, or other systems that require energy from depletable sources to directly condition the space.

Direct and indirect evaporation of water alone is not considered mechanical cooling. Therefore, air cooled by the evaporation of water can be used as kitchen hood makeup air with no restrictions.

10.3.3.2 Limitations to the Amount of Mechanically Heated or Cooled Airflow for Kitchens

§140.9(b)2A

This section limits the amount of mechanically cooled or heated airflow to any space with a kitchen hood. The amount of mechanically cooled or heated airflow must not exceed the greater of:

1. The supply flow required to meet the space heating or cooling load.
2. The hood exhaust minus the available transfer air from adjacent spaces.

The supply flow required to meet the space heating or cooling loads can be documented by providing the load calculations.

To calculate the available transfer air:

1. Calculate the minimum outside air (OA) needed for the spaces that are adjacent to the kitchen.
2. From the amount calculated in 1, subtract the amount of air used by exhaust fans in the adjacent spaces. This amount includes toilet exhaust and any hood exhaust in adjacent spaces.
3. From the amount calculated in 2, subtract the amount of air needed for space pressurization. The remaining air is available for transfer to the hoods.

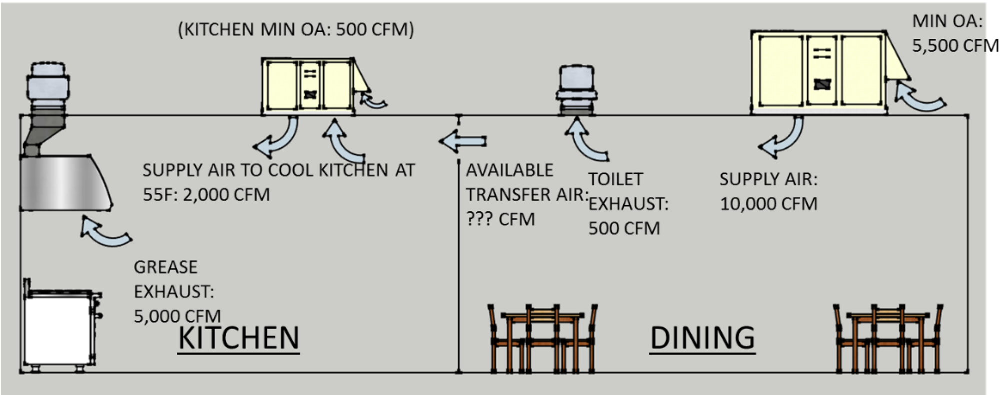
An exception is provided for existing kitchen makeup air units (MAU) that are not being replaced as part of an addition or alternation.

While the requirement to use available transfer air refers only to "adjacent spaces," available transfer air can come from any space in the same building as the kitchen. A kitchen on the ground floor of a large office building, for example, can draw transfer air from the return plenum and the return shaft. The entire minimum OA needed for the building, minus the other exhaust and pressurization needs, is available transfer air. If the return air path connecting the kitchen to the rest of the building is constricted, resulting in high transfer air velocities, then it may be necessary to install a transfer fan to assist the transfer air in making its way to the kitchen. The energy use of a transfer fan is small compared to the extra mechanical heating and cooling energy of an equivalent amount of OA.

Example 10-1:

Question:

What is the available transfer air for the kitchen makeup in the scenario shown in the following figure?



Answer:

5,000 cfm calculated as follows.

The OA supplied to the dining room is 5,500 cfm. From this, subtract 500 cfm for the toilet exhaust and 0 cfm for building pressurization.

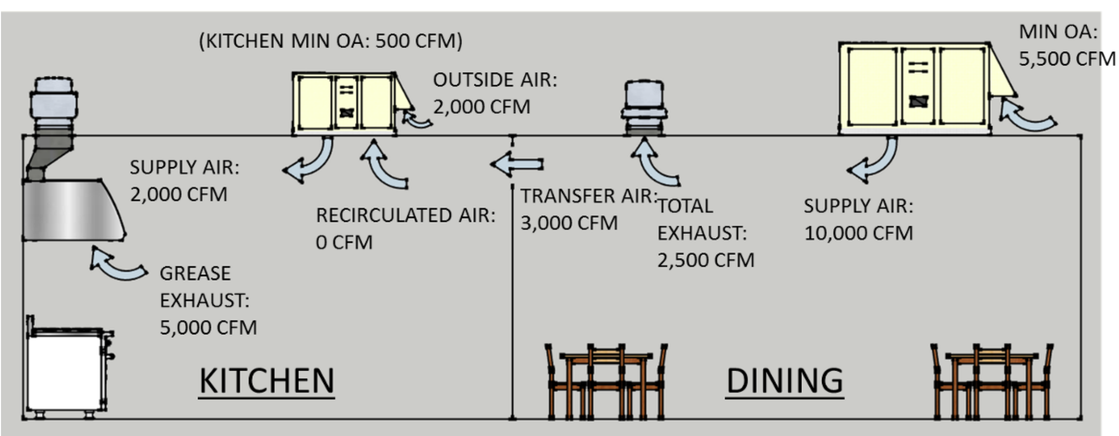
5,500 cfm – 500 cfm – 0 cfm = 5,000 cfm

The remaining 5,000 cfm of air is available transfer air.

Example 10-2:

Question:

Assuming that this kitchen needs 2,000 cfm of supply air to cool the kitchen with a design supply air temperature of 55°F, would the following design airflow meet the requirements of §140.9(b)2A?



Answer:

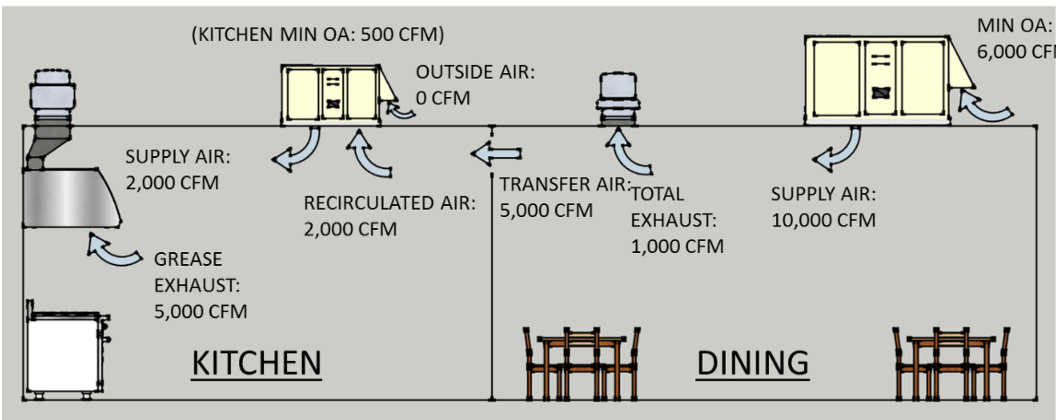
Yes. This example meets the first provision of §140.9(b)2A. The supply flow required to meet the cooling load is 2,000 cfm. Thus, up to 2,000 cfm of mechanically conditioned makeup air can be provided to the kitchen. The supply from the MAU, 2,000 cfm, is not as large as the hood exhaust, 5,000 cfm. This means that the remainder of the makeup air, 3,000 cfm, must be transferred from the dining room space.

Although this is allowed under §140.9(b)2Ai, this is not the most efficient way to condition this kitchen, as demonstrated in the next example.

Example 10-3:

Question:

Continuing with the same layout as the previous example, would the following design airflow meet the requirements of §140.9(b)2A?



Answer:

Yes. In this example, 100 percent of the makeup air, 5,000 cfm, is provided by transfer air from the adjacent dining room. The OA on the unit serving the dining room has been increased to 6,000 cfm to serve the ventilation for both the dining room and kitchen. Since the dining room has no sources of undesirable contaminants, we can ventilate the kitchen with the transfer air.

Comparing this image to the previous, example you will see that this design is more efficient for the following reasons:

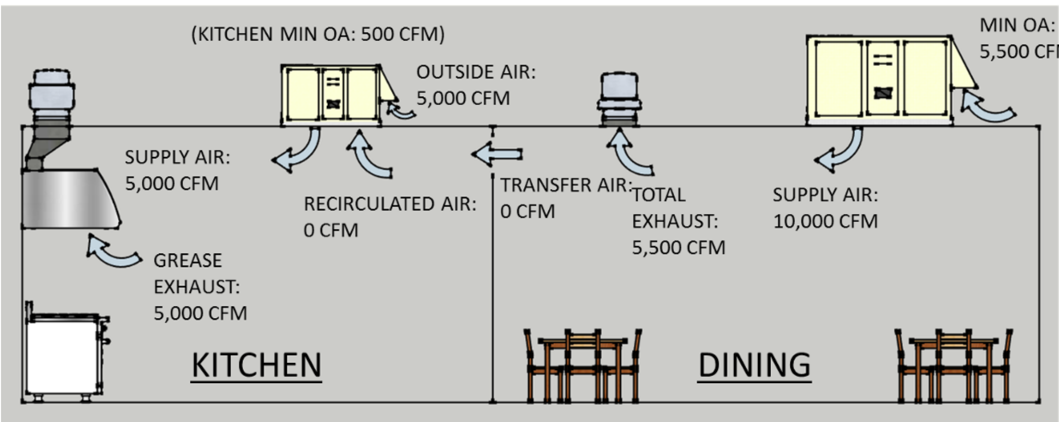
1. The total outside airflow to be conditioned has been reduced from 7,500 cfm in the previous example (2,000 cfm at the MAU and 5,500 cfm at the dining room unit) to 6,000 cfm.
2. The dining room exhaust fan has dropped from 2,500 cfm to 1,000 cfm reducing both fan energy and first cost of the fan.

An even more efficient design would be if the kitchen MAU had a modulating OA damper that allowed it to provide up to 5,000 cfm of outside air directly to the kitchen when OA temperature < kitchen space temperature. When OA temperature > kitchen space temperature, then the OA damper on the MAU is shut, and replacement/ventilation air is transferred from the dining area. This design requires a variable-speed dining room exhaust fan controlled to maintain slight positive pressure in the dining area. This design is the baseline design modeled in the *Alternative Calculation Methods (ACM) Reference Manual* for performance compliance. The baseline model assumes that transfer air is available from the entire building, not just the adjacent spaces.

Example 10-4:

Question:

Continuing with the same layout as the previous examples, would the following design airflow meet the requirements of §140.9(b)2A?



Answer:

Not if the kitchen is mechanically heated or cooled. Per §140.9(b)2A, the maximum amount of makeup air that can be mechanically heated or cooled cannot exceed the greater of:

1. Per §140.9(b)2Ai: 2,000 cfm, the supply needed to cool the kitchen (from Example 10-2)
2. Per §140.9(b)2Aii: 0 cfm, the amount of hood exhaust (5,000 cfm) minus the available transfer air (5,500 - 500 = 5000 cfm; from Example 10-2).

The 5,000 cfm of conditioned makeup air exceeds 2,000 cfm. This example assumes that the required exhaust for the dining space is 500 cfm of bathroom exhaust, and the remaining 5,000 cfm of dining outdoor air is available for transfer to the kitchen.

B. Additional Efficiency Measures for Large Kitchens

§140.9(b)2B

For kitchens or dining facilities that have more than 5,000 cfm of Type I and II hood exhaust, the mechanical system must meet one of the following requirements:

1. At least 50% of all replacement air is transfer air that would have been exhausted.
2. Demand ventilation control on at least 75% of the exhaust air.
3. The listed energy recovery devices have a sensible heat recovery effectiveness ≥40% on ≥50% of the total exhaust flow.
4. Seventy-five percent or more of the makeup air volume is:
   a. Unheated or heated to no more than 60°F.
   b. Uncooled or cooled without the use of mechanical cooling.

Exception to 140.9(b)2B: Existing hoods not being replaced as part of an addition or alteration.

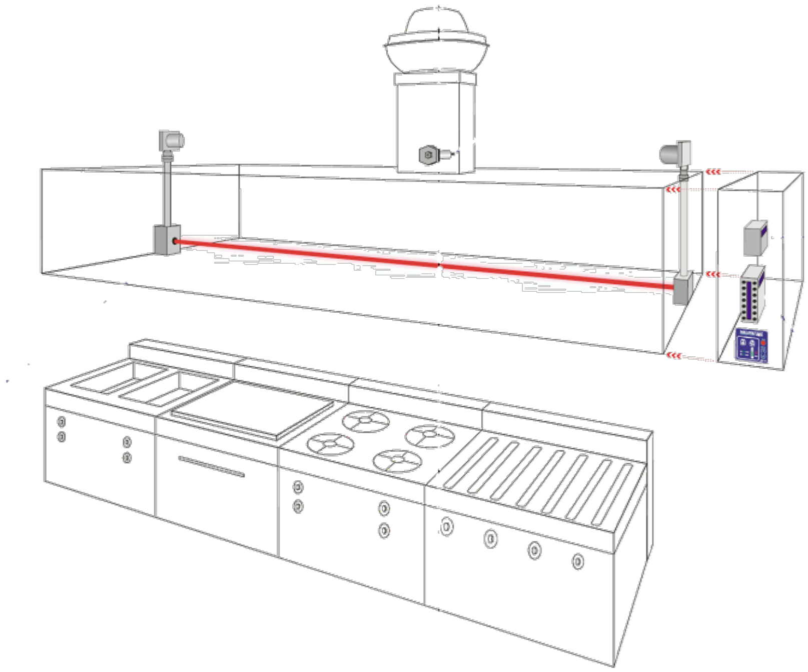
Transfer Air: The concept of transfer air was addressed in the discussion of §140.9(b)2A above.

Demand Ventilation Control: Per §140.9(b)2Bii, demand ventilation controls must have all the following characteristics:

a. Include controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent, and combustion products during cooking and idle.
b. Include failsafe controls that result in full flow upon cooking sensor failure.
c. Include an adjustable timed override to allow occupants the ability to temporarily override the system to full flow.
d. Be capable of reducing exhaust and replacement air system airflow rates to the larger of:
   1. 50 percent of the total design exhaust and replacement air system airflow rates.
   2. The ventilation rate required in §120.1.

There are several off-the-shelf technologies that use smoke detectors that can comply with all these requirements.

Figure 10-3: Demand Control Ventilation Using a Beam Smoke Detector



Source: California Energy Commission

Energy Recovery: Energy recovery is provided using air to air heat exchangers between the unit providing makeup air and the hood exhaust. This option is most effective for extreme climates (either hot or cold) and less commonly used in the mild climates of California.

Tempered Air With Evaporative Cooling: The final option is to control the heating (if there is heating) to a space by setting the temperature set point to 60°F and to use evaporative (non-compressor) cooling or no cooling at all for 75 percent of the makeup air.

10.3.3.3 Kitchen Exhaust Acceptance

§140.9(b)3

Acceptance tests for these measures are detailed in NA7.11. See Chapter 13 of this manual.

10.3.3.4 Healthcare Facilities

Healthcare facilities are not required to meet 140.9(b).

10.3.4 Additions and Alterations

See above sections for specific applications of these measures to additions and alterations.

10.4 Computer Rooms

10.4.1 Overview

Sections 120.6(j), 140.9(a) and 141.1(b) provides minimum requirements for *computer rooms*. A *computer room* is defined in §100.1 as "a room within a building whose primary function is to house electronic equipment and that has a design information technology equipment (ITE) equipment power density exceeding 20 watts/ft^2 (215 watts/m^2) of conditioned floor area." ITE is defined in §100.1 Definitions and "includes computers, data storage, servers, and network/communication equipment located in a computer room."

10.4.2 Mandatory Measures

There are three mandatory measures specific to computer rooms:

a. Reheat - §120.6(j)1

b. Humidification - §120.6(j)2, and

c. Fan Control - §120.6(j)3.

The equipment efficiencies in §110.1 and §110.2 also apply.

10.4.2.1 Reheat

§120.6(j)1

Section 120.6(j)1 prohibits reheating, recooling, or simultaneous heating and cooling in c*omputer rooms*. Furthermore, the definition of cooling includes both *mechanical cooling* and e*conomizers.* This provision is to prohibit use of CRAC and CRAH units with humidity controls that include reheat coils.

10.4.2.2 Humidification

§120.6(j)2

Section 120.6(j)2 prohibits the use of nonadiabatic humidification for *computer rooms*. The requirement of humidity control in *computer rooms* is controversial. On the low-humidity side, humidification was provided to reduce the risk of electrostatic discharge. On the high-humidity side, the concern has been printed circuit board failure due to circuit board metallic filament formations known as conductive anodic filaments. For both of these issues, there is insufficient evidence that the risks are adequately addressed through the use of humidity controls. The telecommunications industry standard for central office facilities has no restrictions on either the low or high humidity limits. Furthermore, the Electrostatic Discharge Association (ESDA) removed humidification as a primary control over electrostatic discharge in electronic manufacturing facilities (ANSI/ESD Standard 20.20) because it was not effective and did not supplant the need for personal grounding. The Energy Code allows for humidification but prohibits the use of nonadiabatic humidifiers, including the steam humidifiers and electric humidifiers that rely on boiling water as both of these add cooling load with the humidity. The technologies that meet the adiabatic requirement are direct evaporative cooling and ultrasonic humidifiers.

10.4.2.3 Fan Control

§120.6(j)3

Section 120.6(j)3 requires that fans serving *computer rooms* have either variable-speed control or two-speed motors that provide for a reduction in fan motor power to ≤50% of power at design airflow when the airflow is at 66% of design airflow. This applies to chilled water units of all sizes and DX units with a rated cooling capacity of ≥ 5 tons.

10.4.3 Prescriptive Measures

The following is a summary of measures for new construction computer rooms:

a. Economizers — §140.9(a)1
b. Power consumption of fans — §140.9(a)2
c. Air containment — §140.9(a)3
d. Alternating current-output uninterruptible power supplies — §140.9(a)4.

10.4.3.1 Economizers

§140.9(a)1

This section requires integrated air or water economizers. If an air economizer is used to meet this requirement, it must be designed to provide 100 percent of the expected system cooling load at outside temperatures of 65°F dry bulb (Tdb) and below or at outside temperatures of 50°F wet bulb (Twb) and below. This is different from the noncomputer-room economizer regulations (§140.4[e]), which require that an air economizer must supply 100 percent of the supply air as outside air. A computer room air economizer does not have to supply any outside air if it has an air-to-air heat exchanger that can meet the expected load at the conditions specified and can be shown (through modeling) to consume no more energy than the standard air economizer. Furthermore, air handlers with cooling capacity greater than 33,000 Btu/hr and air economizers must be equipped with fault detection and diagnostic devices meeting §120.2(i).

If a water economizer is used to meet this requirement, it must be capable of providing 100 percent of the expected system cooling load at outside temperatures of 50°F dry bulb and below or at outside temperatures of 45°F wet bulb and below.

See Chapter 4 for a description of integrated air and water economizers and implementation details.

There are two exceptions to this requirement:

1. **Exception 1 to §140.9(a)1**: Computer rooms with an ITE design load less than 5 tons in a building that does not have any economizers. The computer room exception applies only if none of the other cooling systems in the building includes an economizer. The analysis for this requirement was performed using a 5-ton AC unit with an air/air heat exchanger. Even with the added cost and efficiency loss of a heat exchanger, the energy savings in all the California climates justified this requirement.
2. **Exception 2 to §140.9(a)1**: Applies to computer rooms with an ITE design load less than 20 tons in a larger building with a central air-handling system and complying air-side economizer that can fully condition the computer rooms on weekends and evenings when the other building spaces are unoccupied. This exception allows the computer rooms to be served by fan coils or split system direct expansion (DX) units as long as the following conditions are met:
    a. The economizer system on the central air-handling unit is sized sufficiently that all the computer rooms are less than 50 percent of the total airflow capacity and the economizer system can provide full economizer cooling to the computer room at outside temperatures of 65°F dry bulb and below or at outside temperatures of 50°F wet bulb and below.
    b. The central air-handling unit is configured to serve only the computer rooms if all the other spaces are unoccupied.

Example 10-5:

Question:

A new data center is built with a total computer room load of 1,500 tons. If the *computer rooms* are all served using recirculating chilled water computer room air-handling units (CRAHs) in in-row air-handling units (IRAHs), would this data center meet the requirements of §140.9(a)1 if the chilled water plant had a water-side economizer that complied with the requirements of §140.4(e)?

Answer:

Yes, if the economizer can meet 100 percent of the 1,500-ton load at 50°F dry bulb and below or 45°F wet bulb and below. The design conditions in §140.9(a) would require a different heat exchanger and cooling towers than the conditions in §140.4(e) for nonprocess spaces for a given expected load. The load on the cooling towers, while in economizer-only mode, is lower than the design load even if the computer room load is constant because the towers do not have to reject the heat from the chillers. Furthermore, there are no redundancy requirements in the energy code. Many data centers have more cooling towers than needed to meet the design load so that the design load can be met even if one or more towers is not available. If the system is capable of running all cooling towers in economizer-only mode, then all towers can be included in the calculation for determining compliance with this requirement.

Example 10-6:

Question:

A new data center is built with chilled water CRAH units sized to provide 100 percent of the cooling for the IT equipment. The building also has louvered walls that can open to bring in outside air and fans on the roof that can exhaust air. Does this design meet the requirements of §140.9(a)1?

Answer:

Yes, provided that all the following are true:

- The economizer system moves sufficient air so that it can fully satisfy the design IT equipment loads with the CRAH units turned off and the outside air dry bulb temperature at 65°F and below.
- The control system provides integrated operation so that the chilled water coils in the CRAH units are staged down when cool outside air is brought into the data center.
- The economizer system is provided with a high limit switch that complies with §140.4(e). Although fixed dry bulb switches are allowed in §140.4(e) they are not recommended in this application as the set points were based on office occupancies. A differential dry bulb switch would provide greater energy savings.
- Moreover, because the system economizer is separate from the air handler, FDD is not required.

Example 10-7:

Question:

A new office building has a central air system with variable-air-volume (VAV) boxes with reheat with an air-side economizer that complies with §140.4(e). This building has two intermediate distribution frame (IDF) rooms with split system DX units; one is 4 tons of capacity, and the other is 7-1/2 tons of capacity. Do the IDF rooms meet the requirements of the Energy Code?

Answer:

Not necessarily. Both IDF rooms are required to be served by the central air system economizer of the building. The 4-ton IDF room does not meet Exception 1 to §140.9(a)1 because it is a building with an economizer. Per Exception 4 to §140.9(a)1, the IDF rooms can also be served by split-system DX units without economizers if they are also served by VAV boxes from the VAV reheat system. The DX units must be off when the VAV reheat system has enough spare capacity to meet the IDF loads. The VAV reheat system must be at least twice the capacity of all the IDF rooms. When the office spaces are expected to be unoccupied (for example, at night), the VAV boxes must be shut so that the VAV system can serve only the IDF rooms.

Example 10-8:

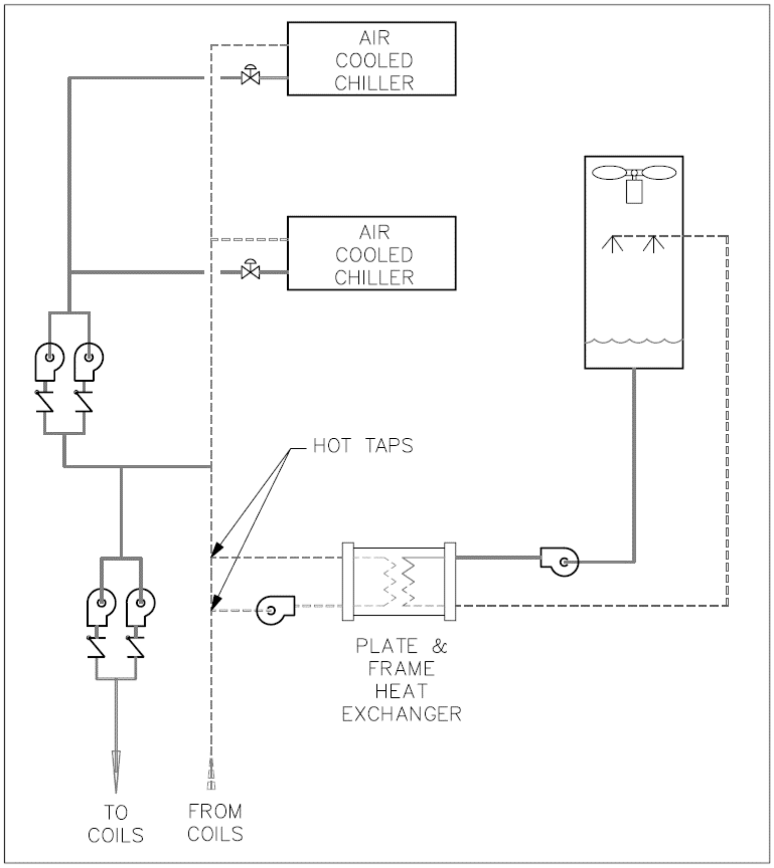
Question:

A new data center employs rear-door heat exchangers that are cooled entirely with water that comes from a closed-circuit fluid cooler. Does this design meet the economizer requirements of §140.9(a)1?

Answer:

Yes. The standard definitions for *economizer* (both air and water) both have the phrase "to reduce or eliminate the need for *mechanical cooling*." In turn, the definition of *mechanical cooling* is "lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy from depletable sources to directly condition the space." Since this system does not use compressors, it complies.

Figure 10-4: Example of Water-Side Economizer Retrofit on a Chilled Water Plant With Air-Cooled Chillers



Source: Energy Code

10.4.3.2 Power Consumption of Fans

§140.9(a)2

In §140.9(a)2, fan power for equipment cooling computer rooms is limited to 27W/kBtuh of net sensible cooling capacity. "Net sensible cooling capacity" is the sensible cooling capacity of the coil minus the fan heat. Systems that are designed for a higher airside ΔT (e.g., 25°F) will have an easier time meeting this requirement than systems designed for lower ΔT (e.g., 15°F)

10.4.3.3 Air Containment

§140.9(a)3

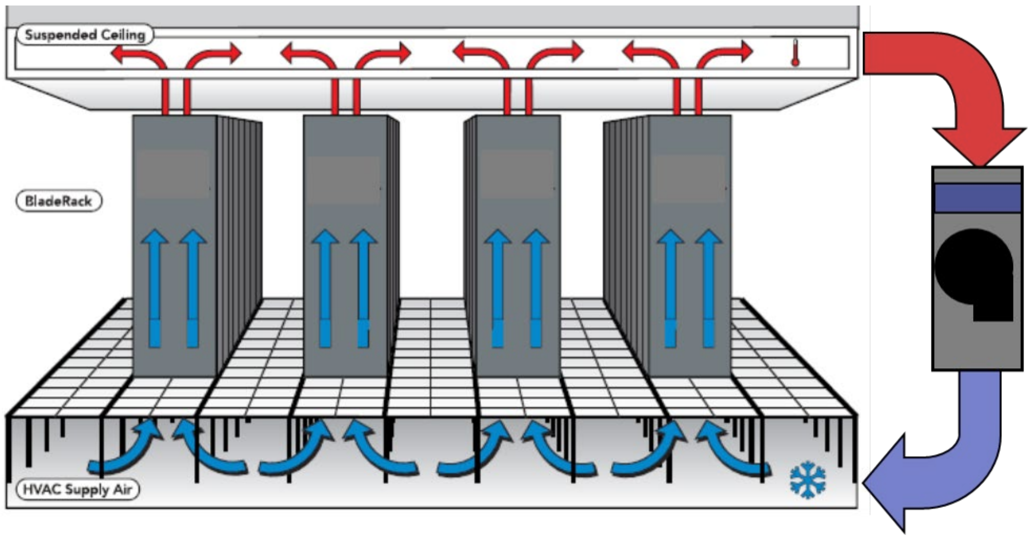
Computer rooms with a design IT equipment load exceeding 10 kW per room are required to have containment to separate the computer equipment inlets and outlets. The requirement can be met using hot-aisle containment, cold-aisle containment, or in-rack cooling. Exceptions are provided for:

a. Expansions of existing *computer rooms* that don't already have containment.

b. Computer racks with a design load of < 1 kW/rack (for example, network racks).

c. Equivalent energy performance demonstrated to the AHJ through use of CFD or other analysis tools.

Figure 10-5: Example of Aisle Containment Using Chimney Racks



Source: California Energy Commission

Figure 10-6: Example of Aisle Containment Using Hard Partitions and Doors

10.4.3.4 §140.9(a)4 Minimum Uninterruptible Power Supply (UPS) Efficiency

Section 140.9(a)4 requires that any alternating current-output UPS installed for computer room equipment meet or exceed calculation and testing requirements identified in ENERGY STAR Program Requirements for UPSs – Eligibility Criteria Version 2.0 and that UPS meets or exceeds the minimum average efficiencies in Table 140.9-B. There are three categories of UPSs identified in Table 140.9-B:

- Voltage and frequency dependent
- Voltage independent
- Voltage and frequency independent.

10.4.4 Additions and Alterations

The following is a summary of measures for additions and alterations for computer rooms:

a. Economizers - §141.1(b)1.

The equipment efficiencies in §120.6(j), 140.9(a)2, and §140.9(a)4 also apply.

10.4.5.1 Economizers

This section requires integrated air or water economizers. If an air economizer is used to meet this requirement, it must be designed to provide 100 percentof the expected system cooling load at outside temperatures of 55°F dry bulb (Tdb) and below or at outside temperatures of 50°F wet bulb (Twb) and below. This is different from the noncomputer-room economizer regulations (§140.4[e]), which require that an air economizer must supply 100 percent of the supply air as outside air. A computer-room air economizer does not have to supply any outside air if it has an air-to-air heat exchanger that can meet the expected load at the conditions specified and can be shown (through modeling) to consume no more energy than the standard air economizer. Furthermore, air handlers with cooling capacity greater than 33,000 Btu/hr and air economizers must be equipped with fault detection and diagnostic devices meeting §120.2(i).

If a water economizer is used to meet this requirement, it must be capable of providing 100 percent of the expected system cooling load at outside temperatures of 40°F dry bulb and below or at outside temperatures of 35°F wet bulb and below.

1. **Exception 1 to §141.1(b)**: Computer rooms with an ITE design load less than 5 tons in a building that does not have any economizers. The computer room exception applies only if none of the other cooling systems in the building includes an economizer.
2. **Exception 2 to §141.1(b)**: New cooling systems serving an existing computer room in an existing building up to a total of 50 tons of new ITE design load per building.

This exception recognizes that an existing space with capacity for future expansion may not have been sited or configured to accommodate access to outside air.

Above 50 tons IT equipment load you would be forced to either provide economizer cooling or offset the energy loss by using the performance approach. Examples of how to meet this requirement include:

a. Provide the new capacity using a new cooling system that has a complying air or water economizer.

b. If the facility has a chilled water plant, install an integrated water-side economizer with a minimum capacity equal to the new computer room cooling load. Water-side economizers can be added to both air- and water-cooled chilled water plants.

3. **Exception 3 to §141.1(b)**: New cooling systems serving a new computer room up to a total of 20 tons of ITE load in an existing building.

   This is similar to the previous exception, but the capacity threshold is lower because you can locate a new space in a location suitable for an integrated economizer.

10.5 Commercial Refrigeration

10.5.1 Overview

This section addresses §120.6(b) of the Energy Code, which covers mandatory requirements for commercial refrigeration systems in retail food stores. This section explains the mandatory requirements for condensers, compressor systems, refrigerated display cases, and refrigeration heat recovery. All buildings under the Energy Code must also comply with the general provisions of the Energy Code (§100.0 – §100.2, §110.0 – §110.10, §120.0 – §120.9, §130.0 – §130.5) and additions and alterations requirements (§141.1).

10.5.1.1 Mandatory Measures and Compliance Approaches

The energy efficiency requirements for commercial refrigeration are all mandatory. There are no prescriptive requirements or performance compliance paths for commercial refrigeration. Since the provisions are all mandatory, there are no trade-offs allowed between the various requirements. The application must demonstrate compliance with each of the mandatory measures. Exceptions to each mandatory requirement where provided are described in each of the mandatory measure sections below.

10.5.1.2 What’s New in the 2022 Energy Codes

In the 2022 Energy Code, adiabatic condenser efficiency and size requirements have been added. Section 120.6(b) 1D and 1E along with Table 120.6 – D have been updated with new requirements for adiabatic condenser systems using halocarbon refrigerant.

10.5.1.3 Scope and Application

§120.6(b)

Section 120.6(b) of the Energy Code applies to retail food or beverage stores that have 8,000 square feet or more of conditioned area and use either refrigerated display cases or walk-in coolers or freezers. The Energy Code has minimum requirements for the condensers, compressor systems, refrigerated display cases, and refrigeration heat-recovery systems associated with the refrigeration systems in these facilities.

The Energy Code does not have minimum efficiency requirements for walk-ins, as these are deemed appliances and are covered by the California Appliance Efficiency Regulations (Title 20) and federal Energy Independence and Security Act of 2007. *Walk-ins* are defined as refrigerated spaces with less than 3,000 square feet of floor area that are designed to operate below 55°F (13°C). Furthermore, the Energy Code does not have minimum equipment efficiency requirements for refrigerated display cases, as the minimum efficiency for these units is established by federal law in the Commercial Refrigeration Equipment Final Rule, but there are requirements for display cases that do result in reduced energy consumption.

Example 10-9:

Question:

The only refrigeration equipment in a retail food store with 10,000 square feet of conditioned area is self-contained refrigerated display cases. Does this store need to comply with the requirements for commercial refrigeration?

Answer:

No. Since the refrigerated display cases are not connected to remote compressor units or condensing units, the store does not need to comply with the Energy Code.

Example 10-10:

Question:

A new retail store with 25,000 square feet conditioned area has two self-contained display cases. The store also has several display case lineups and walk-in boxes connected to remote compressors systems. Do all the refrigeration systems need to comply with the requirements for commercial refrigeration?

Answer:

There are no provisions in the Energy Code for the two self-contained display cases. The refrigeration systems serving the other fixtures must comply with the Energy Code.

10.5.2 Condenser Mandatory Requirements

§120.6(b)1

This section addresses the mandatory requirements for condensers serving commercial refrigeration systems. These requirements apply only to stand-alone refrigeration condensers and do not apply to condensers that are part of a unitary condensing unit.

If the work includes a new condenser replacing an existing condenser, the condenser requirements do not apply if all the following conditions apply:

1. The total heat of rejection of the compressor system attached to the condenser or condenser system does not increase.
2. Less than 25 percent of the attached refrigeration system compressors (based on compressor capacity at design conditions) are new.
3. Less than 25 percent of the display cases (based on display case design load at applied conditions) that the condenser serves are new. Since the compressor system loads commonly include walk-ins (both for storage and point-of-sale boxes with doors), the 25 percent “display case" should be calculated with walk-ins included.

Example 10-11:

Question:

A supermarket remodel includes a refrigeration system modification where some of the compressors will be replaced, some of the refrigerated display cases will be replaced, and the existing condenser will be replaced. The project does not include any new load, and the design engineer has determined that the total system heat of rejection will not increase. The replacement compressors comprise 20 percent of the suction group capacity at design conditions, and the replacement display cases comprise 20 percent of the portion of the design load that comes from display cases. There are no changes in walk-ins. Does the condenser have to comply with the provisions of the Energy Code?

Answer:

No. This project meets all three criteria of the exception to the mandatory requirements for condensers:

1. The new condenser is replacing an existing condenser.

2. The total heat of rejection of the subject refrigeration system does not increase.

3a. The replacement compressors comprise less than 25 percent of the suction group design capacity at design conditions.

3b. The replacement display cases comprise less than 25 percent of the portion of the design load that comes from display cases.

10.5.2.1 Condenser Fan Control

§120.6(b)1A,B,& C

Condenser fans for new air-cooled, evaporative, or adiabatic condensers; fans on air- or water-cooled fluid coolers; or cooling towers used to reject heat on new refrigeration systems must be continuously variable-speed controlled. Variable-frequency drives are commonly used to provide continuously variable-speed control of condenser fans and controllers designed to vary the speed of electronically commutated motors are increasingly being used for the same purpose. All fans serving a common high side, or indirect condenser water loop, shall be controlled in unison. Thus, in normal operation, the fan speed of all fans within a single condenser or set of condensers serving a common high side should modulate together, rather than running fans at different speeds or staging fans off. However, when fan speed is at the minimum practical level, usually no higher than 10–20 percent, the fans may be staged off to reduce condenser capacity. As load increases, fans should be turned back on before significantly increasing fan speed, recognizing a control band is necessary to avoid excessive fan cycling. Control of air-cooled condensers may also keep fans running and use a holdback valve on the condenser outlet to maintain the minimum condensing temperature. Once all fans have reached minimum speed, the holdback valve is set below the fan control minimum saturated condensing temperature set point.

To minimize overall system energy consumption, the condensing temperature control set point must be continuously reset in response to ambient temperatures, rather than using a fixed set point value. This strategy is also termed ambient-following control, ambient-reset, wet bulb-following, and dry bulb-following — all referring to control logic that changes the condensing temperature control set point in response to ambient conditions at the condenser. The control system calculates a control set point saturated condensing temperature that is higher than the ambient temperature by a predetermined temperature difference (in other words, the condenser control temperature difference). Fan speed is then modulated so that the measured saturated condensing temperature (SCT) matches the calculated SCT control set point. The SCT control set point for evaporative condensers or water-cooled condensers (via cooling towers or fluid coolers) must be reset according to the ambient wet bulb temperature, and the SCT control set point for air-cooled condensers must be reset according to ambient dry bulb temperature. The target SCT for adiabatic condensers when operating in dry mode must be reset according to ambient dry bulb temperature. There is no requirement for SCT control during wet-mode (adiabatic) operation. Systems served by adiabatic condensers in Climate Zone 16 are exempted from this control requirement.

The condenser control TD is not specified in the Energy Code. The nominal control value is often equal to the condenser design TD. However, the value for a particular system is left up to the system designer. Since the intent is to use as much condenser capacity as possible without excessive fan power, the common practice is to optimize the control TD over a period such that the fan speed is in a range of around 60–80 percent during normal operation (that is, when not at minimum SCT and not in heat recovery).

The minimum saturated condensing temperature set point must be 70°F (21°C) or less. For systems using halocarbon refrigerants with glide, the SCT set point shall correlate with a midpoint temperature (between the refrigerant bubble-point and dew point temperatures) of 70°F (21°C) or less. As a practical matter, a maximum SCT set point is also commonly employed to set an upper bound on the control set point in the event of a sensor failure and to force full condenser operation during peak ambient conditions. This value should be set high enough that it does not interfere with normal operation.

Split air-cooled condensers are sometimes used for separate refrigeration systems, with two circuits and two rows of condenser fans. Each condenser half would be controlled as a separate condenser. If a condenser has multiple circuits served by a common fan or set of fans, the control strategy may use the average condensing temperature or the highest condensing temperature of the circuits as the control variable for controlling fan speed.

Alternative control strategies are permitted to the condensing temperature reset control required in §120.6(b)1C. The alternative control strategy must be demonstrated to provide equal or better performance, as approved by the executive director.

Air-cooled condensers with separately installed evaporative precoolers added to the condenser are not considered adiabatic condensers for this standard and must meet the requirements for air-cooled equipment, including specific efficiency and ambient-following control.

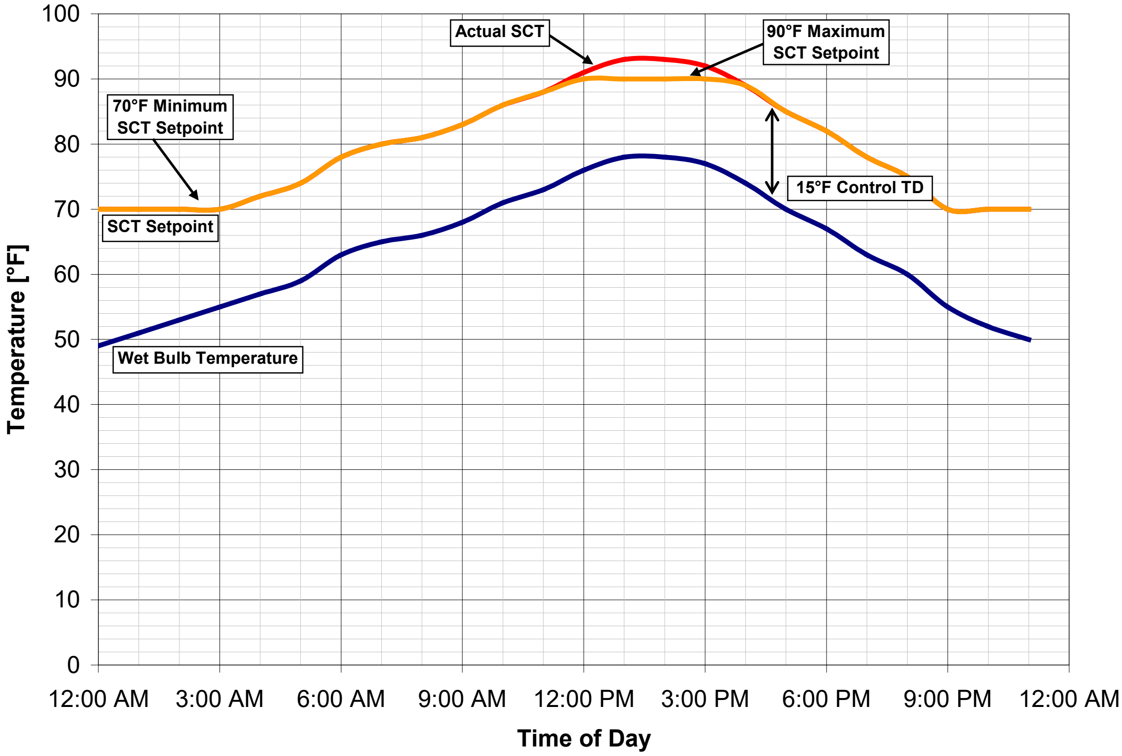
Example 10-12:

Question:

A new supermarket with an evaporative condenser is being commissioned. The control system designer has used a wet bulb-following control strategy to reset the system-saturated condensing temperature (SCT) set point. The refrigeration engineer has calculated that adding a TD of 15°F (8.3°C) above the ambient wet bulb temperature should provide a saturated condensing temperature set point that minimizes the combined compressor and condenser fan power usage throughout the year. What might the system SCT and SCT set point trends look like over an example day?

Answer

The following figure illustrates what the actual saturated condensing temperature and SCT set points could be over an example day using the wet bulb-following control strategy with a 15°F (8.3°C) TD and also observing the 70°F (21°C) minimum condensing temperature requirement. As the figure shows, the SCT set point is continuously reset to 15°F (8.3°C) above the ambient wet bulb temperature until the minimum SCT set point of 70°F is reached. The figure also shows a maximum SCT set point (in this example, 90°F (32.2°C), which may be used to limit the maximum control set point, regardless of the ambient temperature value or TD parameter.



10.5.2.2 Condenser-Specific Efficiency

All newly installed evaporative condensers, air-cooled condensers, and adiabatic condensers with capacities greater than 150,000 Btuh (at the specific efficiency rating conditions) shall meet the minimum specific efficiency requirements shown in Table 10-2.

Table 10-2: Fan-Powered Condensers – Minimum Specific Efficiency Requirements

Condenser Type	Minimum Specific Efficiency	Rating Condition
Evaporative-Cooled	160 Btuh/Watt	100°F Saturated Condensing Temperature (SCT), 70°F Entering Wet bulb Temperature
Air-Cooled	65 Btuh/Watt	105°F Saturated Condensing Temperature (SCT), 95°F Entering Dry bulb Temperature
Adiabatic Dry Mode	45 Btuh/Watt (Halocarbon)	105°F Saturated Condensing Temperature (SCT), 95°F Entering Dry bulb Temperature

Source: California Energy Commission

Condenser specific efficiency is defined as:

Condenser Specific Efficiency = Total Heat Rejection (THR) Capacity/Input Power

The total heat rejection capacity is defined at the rating conditions of 100°F SCT and 70°F outdoor wet bulb temperature for evaporative condensers, and 105°F SCT and 95°F outdoor dry bulb temperature for air-cooled and adiabatic (halocarbon refrigerant only) condensers. Total heat of rejection capacity for adiabatic condensers is based on dry mode ratings (in other words, no precooling of the air). Input power is the electric input power draw of the condenser fan motors (at full speed) plus the electric input power of the spray pumps for evaporative condensers. The motor power is the manufacturer's published applied power for the subject equipment, which is not necessarily equal to the motor nameplate rating. Power input for secondary devices such as sump heaters shall not be included in the specific efficiency calculation.

The data published in the condenser manufacturer's published rating for capacity and power shall be used to calculate specific efficiency. For evaporative condensers, manufacturers typically provide nominal condenser capacity and tables of correction factors that are used to convert the nominal condenser capacity to the capacity at various applied condensing temperatures and wet bulb temperatures. Usually, the manufacturer publishes two sets of correction factors: one is a set of "heat rejection" capacity factors, while the other is a set of "evaporator ton" capacity factors. Only the "heat rejection" capacity factors shall be used to calculate the condenser capacity at the efficiency rating conditions for determining compliance with this section.

For air-cooled and adiabatic condensers, manufacturers typically provide the capacity at a given temperature difference (TD) between SCT and dry bulb temperature. Manufacturers typically assume that air-cooled condenser capacity is linearly proportional to TD; the catalog capacity at 20°F TD is typically twice as much as at 10°F TD. The condenser capacity for air-cooled and adiabatic condensers at a TD of 10°F shall be used to calculate efficiency. If the capacity at 10°F TD is not provided, the capacity shall be scaled linearly.

Depending on the type of condenser, the actual manufacturer's rated motor power may vary from motor nameplate in different ways. Air-cooled condensers with direct-drive original equipment manufacturer (OEM) motors may use far greater input power than the nominal motor horsepower would indicate. On the other hand, evaporative condenser fans may have a degree of safety factor to allow for higher motor load in cold weather conditions (vs. the 100°F SCT/70°F WBT specific efficiency rating conditions). Thus, actual motor input power from the manufacturer must be used for direct-drive air-cooled condensers. For evaporative condensers and fluid coolers, the full load motor power, using the minimum allowable motor efficiencies published in the Nonresidential Appendix NA-3: Fan Motor Efficiencies, is generally conservative, but manufacturer's applied power should be used whenever possible to determine specific efficiency more accurately.

There are three exceptions to the condenser specific efficiency requirements.

1. If the store is located in Climate Zone 1 (the cool coastal region in Northern California).
2. If an existing condenser is reused for an addition or alteration.
3. If the condenser capacity is less than 150,000 Btuh at the specific efficiency rating conditions.

Example 10-13:

Question:

An air-cooled condenser is being designed for a new supermarket. The refrigerant is R-507. The condenser manufacturer's catalog states that the subject condenser has a capacity of 500 MBH at 10°F TD between entering air and saturated condensing temperatures with R-507 refrigerant. Elsewhere in the catalog, it states that the condenser has 10½ hp fan motors that draw 450 watts each. Does this condenser meet the minimum efficiency requirements?

Answer:

First, the condenser capacity must be calculated at the specific efficiency rating condition. From Table 10-6, we see that the rating conditions for an air-cooled condenser are 95°F entering dry bulb temperature and 105°F SCT. The catalog capacity is at a 10°F temperature difference, which is deemed suitable for calculating the specific efficiency (105°F SCT - 95°F entering dry bulb = 10°F TD). Input power is equal to the number of motors multiplied by the input power per motor:

10 fan motors x $\frac{450\ Watts}{fan\ motor}$ *= 4,500 Watts*

The specific efficiency of the condenser is therefore:

500MBH x $\frac{1,000\ Btu/hr\ /\ 4,500Watts}{4,500\ Watts}$ *= 111Btu/hr/Watts*

This condenser has a specific efficiency of 111 Btuh per watt, which is higher than the 65 Btuh per watt minimum requirement. This condenser meets the minimum specific efficiency requirements.

Example 10-14:

Question:

An evaporative condenser is being designed for a new supermarket. The manufacturer's catalog provides a capacity of 2,000 MBH at standard conditions of 105°F SCT and 78°F wet bulb temperature. The condenser manufacturer's catalog provides the following heat rejection capacity factors:

Non-standard Conditions Heat Rejection Capacity			
Saturated Condensing Temperature (°F)	Wet Bulb Temperature (°F)		
	70	75	78
95	1.20	1.35	1.65
100	0.95	1.10	1.25
105	0.80	0.90	1.00

Elsewhere in the catalog, it states that the condenser model has one 10 HP fan motor and one 2 HP pump motor. Fan motor efficiencies and motor loading factors are not provided by the manufacturer. Does this condenser meet the minimum efficiency requirements?

Answer:

First, the condenser capacity must be calculated at the specific efficiency rating condition. From Table 10-6, we see that the rating conditions for an evaporative condenser are 100°F SCT, 70°F WBT, and a minimum specific efficiency requirement is 160 Btuh/watt. From the Heat Rejection Capacity Factors table, we see that the correction factor at 100°F SCT and 70°F WBT is 0.95. The capacity of this model at the specific efficiency rating conditions is:

2,000 MBH/0.95 = 2,105 MBH

To calculate input power, we will assume 100 percent fan and pump motor loading and minimum motor efficiencies since the manufacturer has not yet published actual motor specific efficiency at the specific efficiency rating conditions. We look up the minimum motor efficiency from Nonresidential Appendix NA-3: Fan Motor Efficiencies. For a 10 HP six-pole open fan motor, the minimum efficiency is 91.7 percent. For a 2 HP six-pole open pump motor, the minimum efficiency is 87.5 percent. The fan motor input power is calculated to be:

$$1 \text{ Motor} \times \frac{10 \text{ HP}}{\text{Motor}} \times 746 \frac{\text{watts}}{\text{HP}} \times \frac{100\% \text{ assumed loading}}{91.7\% \text{ efficiency}} = 8{,}135 \text{ watts}$$

The pump motor input power is calculated to be:

$$1 \text{ Motor} \times \frac{2 \text{ HP}}{\text{Motor}} \times 746 \frac{\text{watts}}{\text{HP}} \times \frac{100\% \text{ assumed loading}}{87.5\% \text{ efficiency}} = 1{,}705 \text{ watts}$$

The combined input power is therefore:

8,135 watts + 1,705 watts = 9,840 watts

Note: Actual motor power should be used when available. (See note in text.)

Finally, the efficiency of the condenser is:

$$(2{,}105 \text{ MBH} \times \frac{1{,}000 \text{ Btuh}}{\text{MBH}}) / 9{,}840 \text{ watts} = 214 \text{ Btuh/watt}$$

214 Btuh per watt is higher than the 160 Btuh per watt requirement; this condenser meets the minimum efficiency requirements.

Example 10-15

Question:

An adiabatic condenser is being designed for a new supermarket. The refrigerant is R-407A. The condenser manufacturer's catalogue states that the subject condenser has a capacity of 550 MBH at 10°F TD between entering air dry bulb temperature and saturated condensing temperatures with R-407A refrigerant when operating in dry mode. Elsewhere in the catalog, it states that the condenser has two 5-hp fan motors that draw 4.5 kW each. Does this condenser meet the minimum efficiency requirements?

Answer:

First, the condenser capacity must be calculated at the specific efficiency rating condition. From Table 10-2, we see that the rating conditions for an air-cooled condenser are 95°F entering dry bulb temperature and 105°F SCT. The catalog capacity is rated at a 10°F temperature difference, which is deemed suitable for calculating the specific efficiency (105°F SCT - 95°F entering dry bulb = 10°F TD). Input power is equal to the number of motors multiplied by the input power per motor:

2 fan motors x 4,500 watts = 9,000 watts

The specific efficiency of the condenser is therefore:

(550MBH x 1,000 Btu/hr/MBH) / 9000 watts = 61 Btu/hr/watts

This condenser has a specific efficiency of 61 Btuh per watt, which is higher than the 45 Btuh per watt minimum requirement. This condenser meets the minimum specific efficiency requirements.

10.5.2.3 Condenser Fin Density

Air-cooled condensers shall have a fin density no greater than 10 fins per inch. Condensers with higher fin densities have a higher risk of fouling with airborne debris. This requirement does not apply for air-cooled condensers that use a microchannel heat exchange surface, since this type of surface is not as susceptible to permanent fouling in the same manner as traditional tube-and-fin condensers with tight fin spacing.

The fin spacing requirement does not apply to condensers that are reused for an addition or alteration.

10.5.2.4 Adiabatic Condenser Sizing

§120.6(b)1E

New adiabatic condensers on new refrigeration systems must follow the condenser sizing, fan control, and efficiency requirements as described in §120.6(b)1E.

Condensers must be sized to provide sufficient heat rejection capacity under design conditions while maintaining a specified maximum temperature difference between the refrigeration system SCT and ambient temperature. The design condenser capacity shall be greater than the calculated combined total heat of rejection (THR) of the dedicated compressors that are served by the condenser. If multiple condensers are specified, then the combined capacity of the installed condensers shall be greater than the calculated heat of rejection. When determining the design THR for this requirement, reserve or backup compressors may be excluded from the calculations.

Section 120.6(b)1E provides maximum design SCT values for adiabatic condensers. For this section, designers should use the 0.5 percent design dry bulb temperature (DBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement.

Standard practice is for published condenser ratings to assume the capacity of adiabatic condensers is proportional to the temperature difference (TD) between SCT and DBT for operation in dry mode, regardless of the actual ambient temperature entering the condenser. For example, the capacity of an adiabatic condenser operating at an SCT of 80°F with a DBT of 70°F is assumed to be equal to the same unit operating at 110°F SCT and 100°F DBT during dry mode operation, since the TD across the condenser is 10°F in both examples. Thus, similar to air-cooled condensers, the requirement for adiabatic condensers does not have varying sizing requirements for different design ambient temperatures.

However, the Energy Code has different requirements for adiabatic condensers depending on the space temperatures served by the refrigeration system. The maximum design SCT requirements are listed in Table 10-5 below.

Refrigerated Load Type	Space Temperature	Maximum SCT (dry mode)
Cooler	≥ 28°F	Design DBT plus 30°F
Freezer	< 28°F	Design DBT plus 20°F

Source: California Energy Commission

Often, a single refrigeration system and the associated condenser will serve a mix of cooler and freezer load. In this instance, the maximum design SCT shall be a weighted average of the requirements for cooler and freezer loads, based on the design evaporator capacity of the spaces served.

Example 10-16:

Question:

An adiabatic condenser is being sized for a system that has half of the installed capacity serving cooler space and the other half serving freezer space. What is the design TD to be added to the design dry bulb temperature?

Answer:

Using adiabatic condensers for coolers has a design approach of 30°F and for freezers a design approach of 20°F. When a system serves freezer and cooler spaces, a weighted average should be used based on the installed capacity. To calculate the weighted average, multiply the percentage of the total installed capacity dedicated to coolers by 30°F. Next, multiply the percentage of the total installed capacity de freezers by 20°F. The sum of the two results is the design condensing temperature approach. In this example, the installed capacity is evenly split between freezer and cooler space. As a result, the design approach for the air-cooled condenser is 25°F.

(50% x 20 °F) + (50% x 30°F) = 10 °F + 15 °F = 25 °F

10.5.3 Compressor System Mandatory Requirements

§120.6(b)2

This section addresses mandatory requirements for remote compressor systems and condensing units used for refrigeration. In addition to the requirements described below, all the compressors and all associated components must be designed to operate at a minimum condensing temperature of 70°F (21°C) or less.

10.5.3.1 Floating Suction Pressure Controls

§120.6(b)2A

Compressors and multiple-compressor suction groups must have floating suction pressure control to reset the saturated suction pressure control set point based on the temperature requirements of the attached refrigeration display cases or walk-ins.

Exceptions to the floating suction pressure requirements are:

1. Single compressor systems that do not have continuously variable-capacity capability.
2. Suction groups that have a design saturated suction temperature of 30°F or higher.
3. Suction groups that comprise the high side of a two-stage or cascade system.
4. Suction groups that primarily serve chillers for secondary cooling fluids.
5. Existing compressor systems that are reused for an addition or alteration.

The examples of a two-stage system and a cascade system are shown in Figure 10-7 and Figure 10-8, respectively. Figure 10-9 shows a secondary fluid system.

Figure 10-7: Two-Stage System Using a Two-Stage Compressor

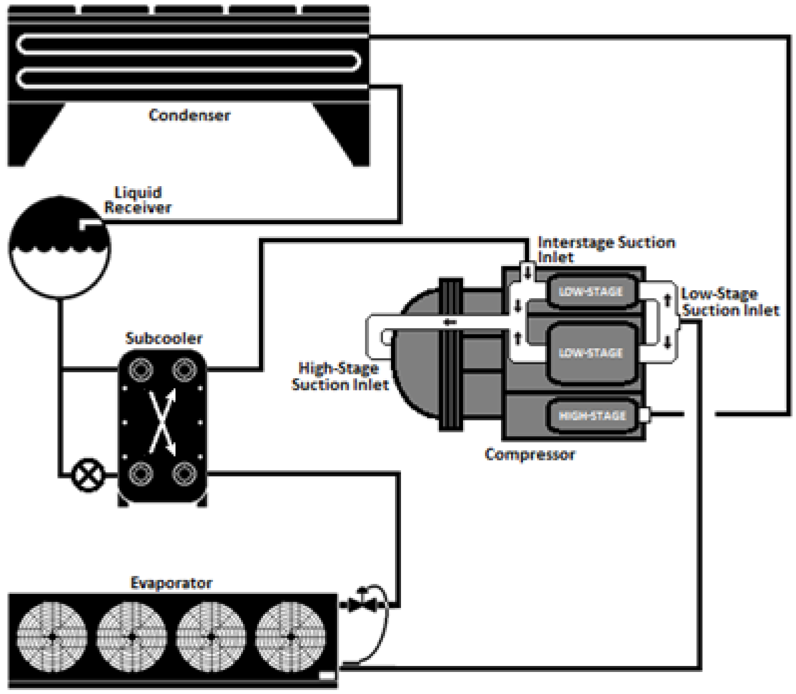


Figure 10-8: Cascade System

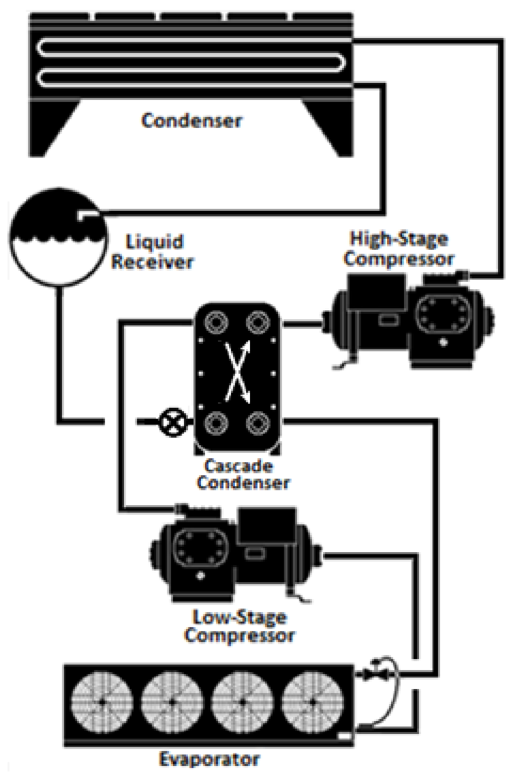
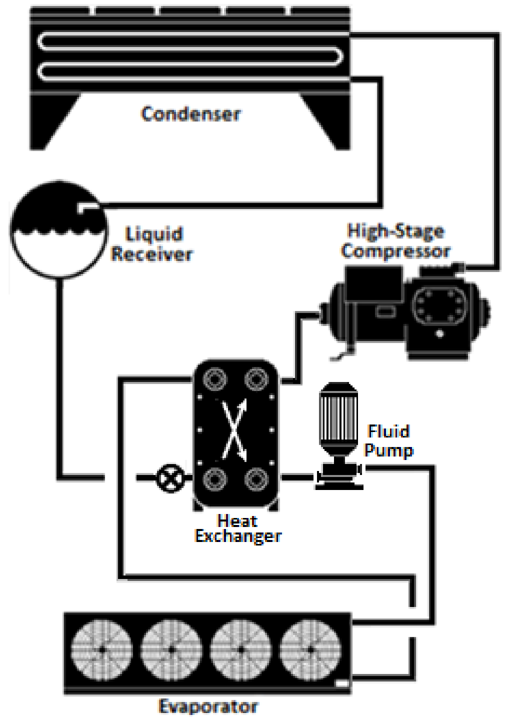


Figure 10-9: Secondary Fluid System



Example 10-17

Question:

A retail food store has four suction groups, A, B1, B2, and C, with design saturated suction temperatures (SST) of -22°F, -13°F, 28°F and 35°F, respectively. System A is a condensing unit. The compressor in the condensing unit is equipped with two unloaders. Suction Group B1 consists of a single compressor with no variable-capacity capability. Suction Group B2 has four compressors with no variable-capacity capability and Suction Group C has three compressors with no variable-capacity capability. Which of these suction groups are required to have floating suction pressure control?

Answer:

Suction Groups A and B2 are required to have floating suction pressure control. The rationale is explained below.

Suction Group A: Although the suction group has only one compressor, the compressor has variable-capacity capability in the form of unloaders. Therefore, the suction group is required to have floating suction pressure control.

Suction Group B1: The suction group has only one compressor with no variable-capacity capability. Therefore, the suction group is not required to have floating suction pressure control.

Suction Group B2: Although the suction group has compressors with no variable-capacity capability, the suction group has multiple compressors that can be sequenced to provide variable-capacity capability. Therefore, the suction group is required to have floating suction pressure control.

Suction Group C: The design SST of the suction group is higher than 30°F. Therefore, the suction group is not required to have floating suction pressure control.

Example 10-18:

Question:

A retail food store has two suction groups, a low-temperature Suction Group A (-22°F design SST) and medium-temperature suction group B (18°F design SST). Suction Group A consists of three compressors. Suction Group B has four compressors that serve a glycol chiller working at 23°F. Which of these suction groups are required to have floating suction pressure control?

Answer:

Suction Group A: The suction group has multiple compressors. Therefore, the suction group is required to have floating suction pressure control.

Suction Group B: Although the suction group has multiple compressors, it serves a chiller for secondary cooling fluid (glycol). Therefore, the suction group is not required to have floating suction pressure control.

Example 10-19:

Question:

A retail food store is undergoing an expansion and has two refrigeration systems: an existing system and a new CO_2 cascade system. The existing system consists of four compressors and a design SST of 18°F. The cascade refrigeration system consists of four low-temperature compressors operating at -20°F SST and three medium-temperature compressors operating at 26°F SST. Which of these systems are required to have floating suction pressure control?

Answer:

Existing system: Although the system has multiple compressors, the compressor system is being reused, and the existing rack controller and sensors may not support floating suction pressure control. Therefore, the system is not required to have floating suction pressure control.

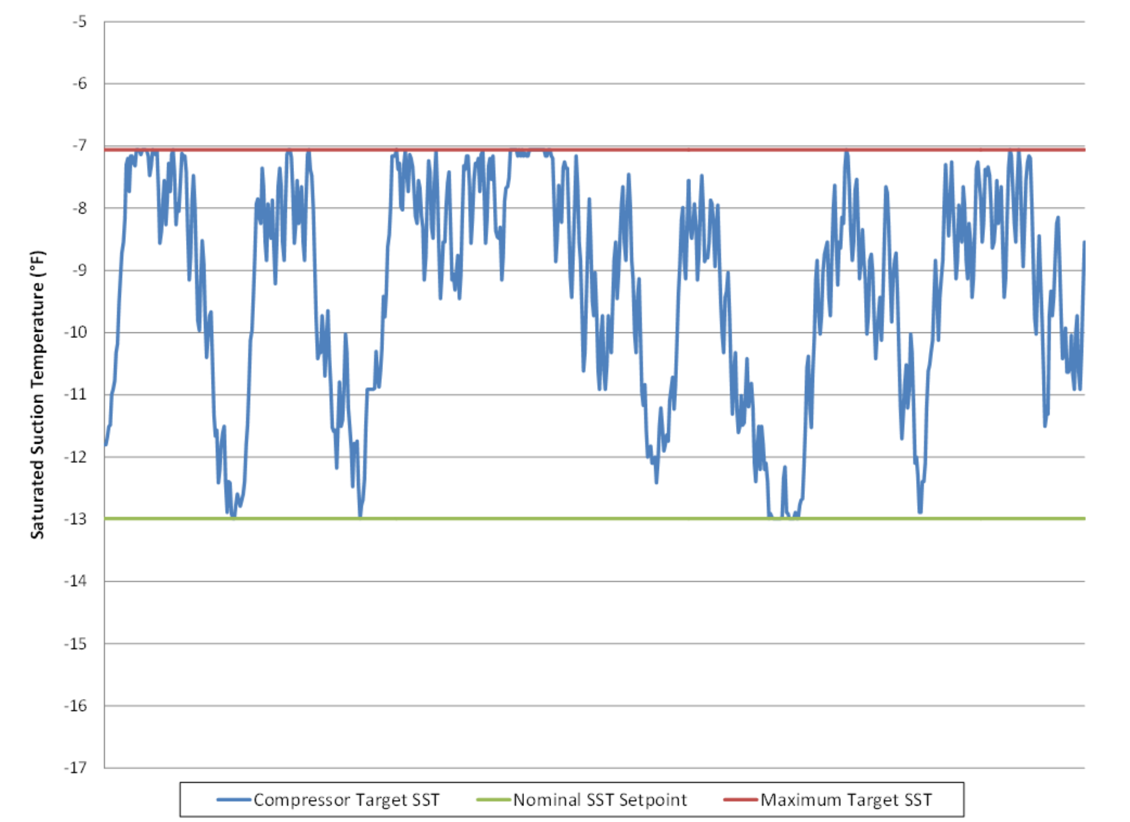
Cascade system: Only the low-temperature suction group of the system is required to have floating suction pressure control.

Evaporator coils are sized to maintain a design fixture temperature under design load conditions. Design loads are high enough to cover the highest expected load throughout the year and inherently include safety factors. The actual load on evaporator coils varies throughout the day, month, and year, and an evaporator coil operating at the design saturated evaporating temperature (SET) has excess capacity at most times. The SET can be safely raised during these times, reducing evaporator capacity and the required "lift" of the suction group, saving energy at the compressor while maintaining proper fixture (and product) temperature.

In a floating suction pressure control strategy, the suction group target saturated suction temperature (SST) set point is allowed to vary depending on the actual requirements of the attached loads, rather than fixing the SST set point low enough to satisfy the highest expected yearly load. The target set point is adjusted so that it is just low enough to satisfy the lowest current SET requirement of any attached refrigeration load while maintaining target fixture temperatures, but not any higher. The controls are typically bound by low and high set point limits. The maximum float value should be established by the system designer, but a minimum value equal to the design SST (that is no negative float) and a positive float range of 4-6°F of saturation pressure equivalent have been used successfully.

Figure 10-10 shows hourly values for floating suction pressure control over one week, expressed in equivalent saturation temperature. The suction pressure control set point is adjusted to meet the temperature set point at the most demanding fixture or walk-in. The difference in SST between the floating suction pressure control and fixed suction pressure control translates into reduced compressor work and, thus, energy savings for the floating suction control.

Figure 10-10: Example of Floating Suction Pressure Control



A. Floating Suction Pressure Control With Mechanical Evaporator Pressure Regulators

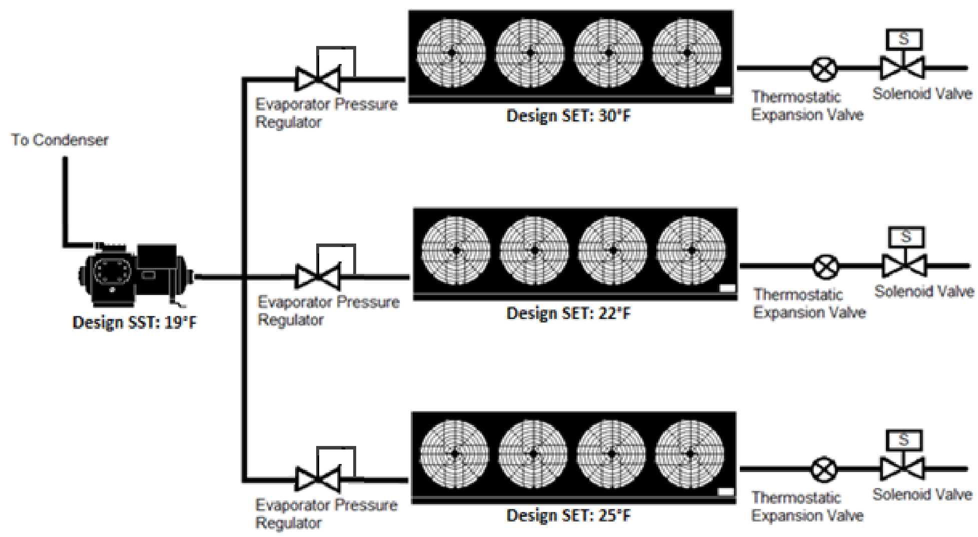
Mechanical evaporator pressure regulators (EPR valves) are often used on multiplex systems to maintain temperature by regulating the SET at each evaporator connected to the common suction group and often to function as a suction stop valve during defrost. EPR valves throttle to maintain the pressure at the valve inlet and, thus, indirectly control the temperature at the case or walk-in. The valves are manually adjusted to the pressure necessary to provide the desired fixture or walk-in air temperature. The load (circuit) with the lowest EPR pressure governs the required compressor suction pressure set point.

Floating suction pressure on a system with EPR valves requires special attention to valve settings on the circuit(s) used for floating suction pressure control. EPR valves on these circuit(s) must be adjusted "out of range," meaning the EPR pressure must be set lower than what would otherwise be used to maintain temperature. This setting keeps the EPR valve from interfering with the floating suction control logic. In some control systems, two circuits are used to govern floating suction control, commonly designated as primary and secondary float circuits. EPR valves may also be equipped with electrically controlled wide-open solenoid pilots for more fully automatic control, if desired.

Similar logic is applied on systems using on/off liquid line solenoid valves for temperature control, with the control of the solenoid adjusted slightly out of range to avoid interference with floating suction pressure.

These procedures have been employed to float suction on supermarket control systems since the mid-1980s; however careful attention is still required during design, start-up, and commissioning to ensure control is effectively coordinated.

Figure 10-11: Evaporators With Evaporative Pressure Regulator Valves



B. Floating Suction Pressure Control with Electronic Suction Regulators

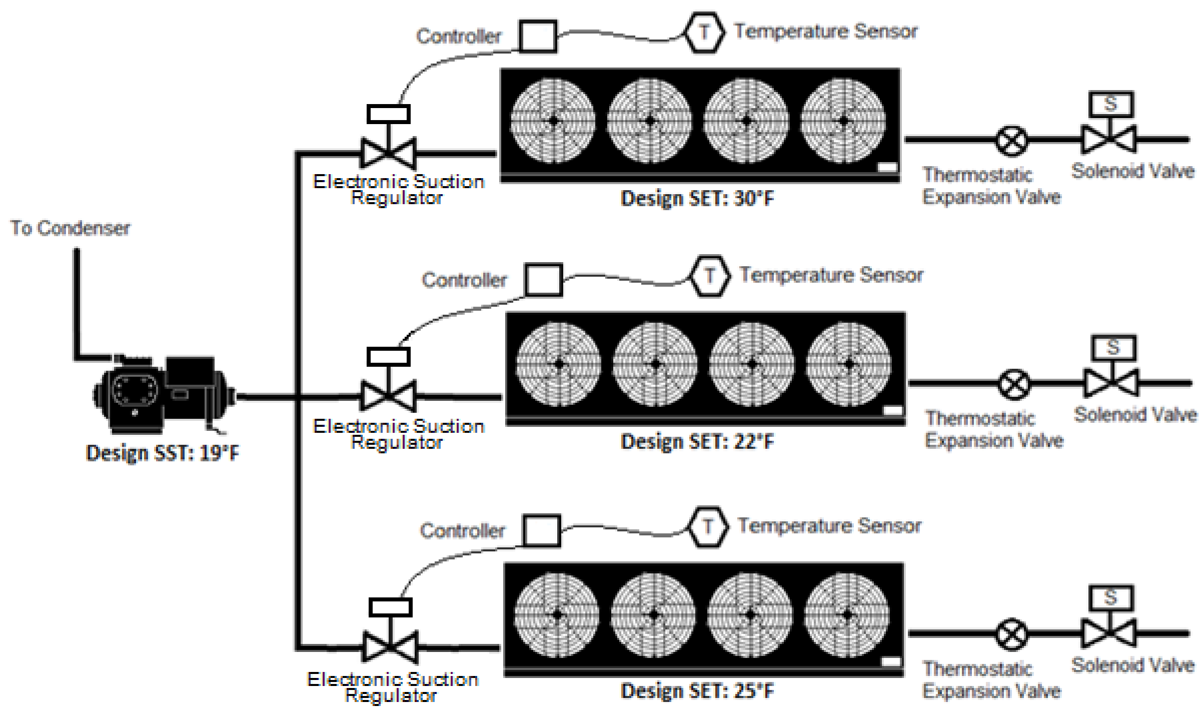
An electronic suction regulator (ESR) valve is an electronically controlled valve used in place of a mechanical evaporator pressure regulator valve. ESRs are also known in the industry as electronic evaporator pressure regulators. ESR valves are not pressure regulators; instead, they control the flow through the evaporator based on a set point air temperature at the case or walk-in. ESR valves are modulated to maintain precise temperature. This modulation provides more accurate temperature compared to an EPR that controls temperature indirectly through pressure and is subject to pressure drop in piping and heat load (and thus TD) on the evaporator coil.

Floating suction pressure strategies with ESR valves vary depending on the controls manufacturer but will generally allow for more flexibility than systems with EPR valves. In general, the control system monitors how much each ESR valve is opened. If an ESR is fully open, indicating that the evaporator connected to the ESR requires more capacity, the control system will respond by decrementing the SST set point. If all ESR valves are less than fully open, the control system increments the suction pressure up until an ESR valve fully opens. At this point, the control system starts floating down the suction pressure again.

This allows suction pressure to be no lower than necessary for the most demanding fixture.

Figure 10-12 shows multiple evaporators controlled by ESR valves connected to a common suction group.

Figure 10-12: DX Evaporators with ESRs on a Multiplex System



10.5.3.2 Liquid Subcooling

§120.6(b)2B

Liquid subcooling must be provided for all low-temperature compressor systems with a design cooling capacity of 100,000 Btuh or greater and a design saturated suction temperature of -10°F or lower. The subcooled liquid temperature of 50°F or less must be maintained continuously at the exit of the subcooler. Subcooling load may be handled by compressor economizer ports or by the use of a suction group operating at a saturated suction temperature of 18°F or higher. Figure 10-13 and Figure 10-14 show example subcooling configurations.

Exceptions to the liquid subcooling requirements are:

1. Low-temperature cascade systems that condense into another refrigeration system rather than condensing to ambient temperature.
2. Existing compressor systems that are reused for an addition or alteration.
3. Transcritical CO_2 refrigeration systems.

Figure 10-13: Liquid Subcooling Provided by Scroll Compressor Economizer Ports

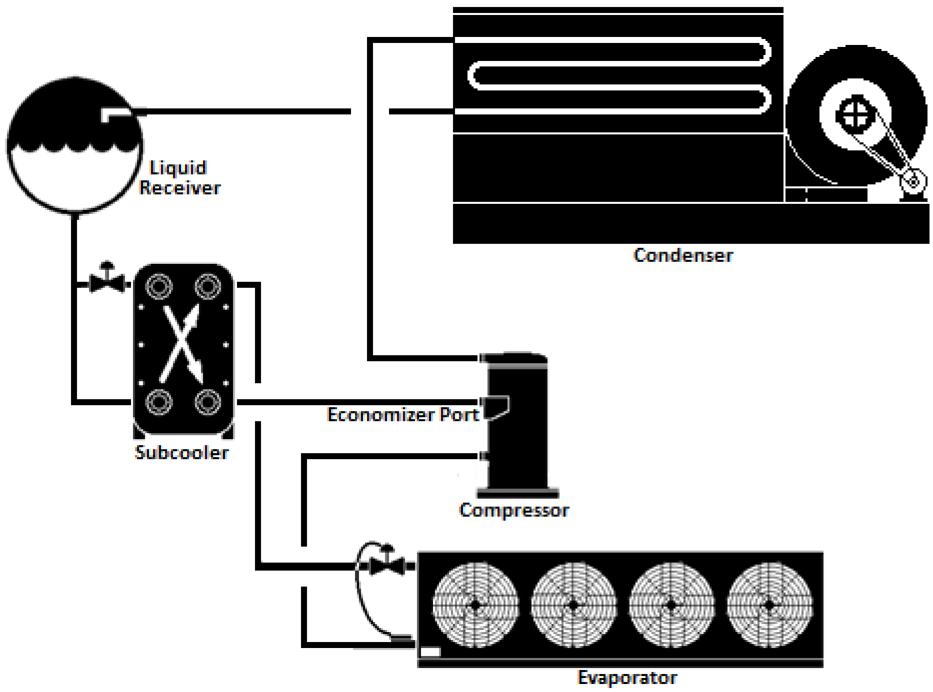
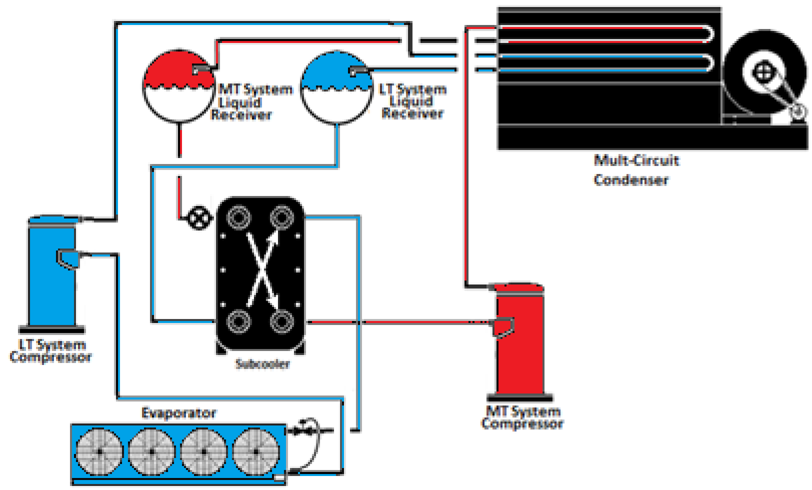


Figure 10-14: Liquid Subcooling Provided by a Separate Medium-Temperature System



10.5.3.1 Compressors for Transcritical CO_2 Refrigeration Systems

§120.6(b)2C

Floating head control is one of the largest energy savings measures applied to refrigeration systems. This control attempts to keep condensing temperatures as low as possible (while not consuming too much gas cooler fan energy) as this reduces compressor head pressure, which directly affects compressor energy.

When ambient temperatures are low, the primary constraint on how low the condensing temperature can be reset is the design requirements of the compressor and associated system components.

Section 120.6(b)2C addresses the compatibility of the compressor design and components with the requirements for floating head control. All compressors that discharge to the gas cooler(s) and all associated components (coalescing oil separators, expansion valves for liquid injection oil cooling, etc.) must be capable of operating at a condensing temperature of 60°F (16°C) or less. Oil separator sizing is often governed by the minimum condensing temperature, as well as other factors, such as the maximum suction temperature. Suction temperatures above the design value may occur under floating suction temperature control schemes.

The system designer should also keep in mind that other design parameters such as piping run lengths or evaporator defrost requirements must be considered to meet this requirement.

The exception to the minimum SCT of 60°F for transcritical CO_2 systems requirement is:

1. Compressors with a design saturated suction temperature greater than or equal to 30°F shall be designed to operate at a minimum condensing temperature of 70°F or less.
2. Existing compressor systems that are reused for an addition or alteration.

10.5.4 Refrigerated Display Case Lighting Control Requirements

§120.6(b)3

All lighting for refrigerated display cases and glass doors of walk-in coolers and freezers shall be controlled by either automatic time switch controls or motion sensor controls or both.

A. Automatic Time Switch Control

Automatic time switch controls shall turn off the lights during nonbusiness hours.

Timed overrides for a display case lineup or walk-in case may be used to turn on the lights for stocking or nonstandard business hours. The override must time-out and automatically turn the lights off again in one hour or less. The override control may be enabled manually (e.g., a push button input to the control system) or may be scheduled by the lighting control or energy management system.

B. Motion Sensor

Motion-sensor control can be used to meet this requirement by either dimming or turning off the display case lights when space near the case is vacated. The lighting must dim so that the lighting power reduces to 50 percent or less. The maximum time delay for the motion sensor must be 30 minutes or less.

10.5.5 Refrigeration Heat Recovery

§120.6(b)4

This section addresses mandatory requirements for the use of heat recovery from refrigeration system(s) to HVAC system(s) for space heating and the charge limitations when implementing heat recovery, including an overview of configurations and design considerations for heat recovery systems. Heat rejected from a refrigeration system is the total of the cooling load taken from display cases and walk-ins in the store plus the electric energy used by the refrigeration compressors. Consequently, there is a natural relationship between the heat available and the heating needed; a store with greater refrigeration loads needs more heat to make up for the cases and walk-ins and has more heat available.

The heat recovery requirements apply only to space heating.

There are many possible heat recovery design configurations due to the variety of refrigeration systems, HVAC systems, and potential arrangement and locations of these systems. Several examples are presented here, but the Energy Code does not require these configurations to be used. The heat recovery design must be consistent with the other requirements in the Energy Code, such as condenser floating head pressure.

At least 25 percent of the sum of the design total heat of rejection (THR) of all refrigeration systems with individual design THR of 150,000 Btu/h or greater must be used for space heat recovery.

Exceptions to the above requirements for heat recovery are:

1. Stores in Climate Zone 15, which is the area around Palm Springs, California. Weather and climate data are available in Joint Appendix JA2 – Reference Weather/Climate Data.
2. The above requirements for heat recovery do not apply to the HVAC and refrigeration systems that are reused for an addition or alteration.
3. Stores that are designed to provide less than 500,000 Btu/h in total heat rejection for all the refrigeration systems in the store combined.

The Energy Code also limits the increase in hydrofluorocarbon (HFC) refrigerant charge associated with refrigeration heat recovery. The increase in HFC refrigerant charge associated with refrigeration heat recovery equipment and piping must not be greater than 0.35 lbs. per 1,000 Btuh of heat recovery heating capacity.

Example 10-20

Question:

A store has three new distributed refrigeration systems, A, B and C, with design THR of 140,000 Btuh, 230,000 Btu/h and 410,000 Btuh, respectively. What is the minimum required amount of refrigeration heat recovery?

Answer:

Refrigeration Systems B and C have design THR of greater than 150,000 Btu/h, whereas Refrigeration System A has a design THR of less than 150,000 Btuh. Therefore, the store must have the minimum refrigeration heat recovery equal to 25 percent of the sum of THR of refrigeration systems B and C only. The minimum required heat recovery is therefore:

25% x (230,000 Btuh + 410,000 Btuh) = 160,000 Btuh

Example 10-21

Question:

How should the THR be calculated for this section?

Answer

The THR value is equal to the total compressor capacity plus the compressor heat of compression.

Example 10-22

Question:

A 35,000 ft^2 food store is expanding to add 20,000 square feet area. The store refrigeration designer plans to use two existing refrigeration systems with 600,000 Btu/h of design total heat rejection capacity and add a new refrigeration system with a design total heat rejection capacity of 320,000 Btu/h. The store mechanical engineer plans to replace all the existing HVAC units. Is the store required to have refrigeration heat recovery for space heating?

Answer:

Yes. The store must have the minimum required refrigeration heat recovery from the new refrigeration system. The new refrigeration system has a design THR of greater than 150,000 Btu/h threshold. The minimum amount of the refrigeration heat recovery is 25 percent of the new system THR. The existing refrigeration systems are not required to have the refrigeration heat recovery.

10.5.5.1 Refrigeration Heat Recovery Design Configurations

The designer of heat recovery systems must consider the arrangement of piping, valves, coils, and heat exchangers as applicable to comply with the Energy Code. Numerous refrigeration heat recovery systems configurations are possible depending upon the refrigeration system type, HVAC system type, and the store size. Some possible configurations are:

1. Direct heat recovery.
2. Indirect heat recovery.
3. Water loop heat pump system.

These configurations are described in more detail with the following sections.

A. Direct Heat Recovery

Figure 10-15 shows a series-connected direct condensing heat recovery configuration. In this configuration, the heat recovery coil is placed directly within the HVAC unit airstream (generally the unit serving the main sales area), and the discharge refrigerant vapor from the compressors is routed through the recovery coil and then to the outdoor refrigerant condenser when in heating mode. If two or more refrigeration systems are used for heat recovery, a multicircuit heat recovery coil could be used.

This configuration is very suitable when the compressor racks are close to the air handling units used for heat recovery. If the distance is too far, an alternative design should be considered; the long piping runs may result in a refrigerant charge increase that exceeds the maximum defined in the Energy Code, or there may be excessive pressure losses in the piping that could negatively affect compressor energy.

Figure 10-15: Series Direct Heat Recovery Configuration

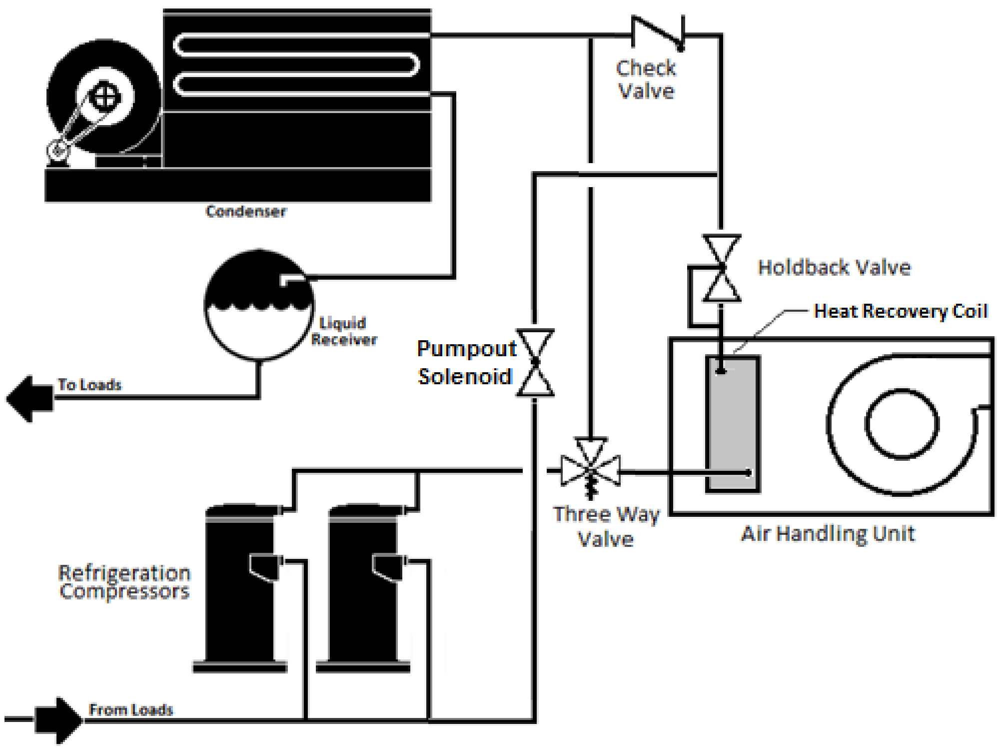
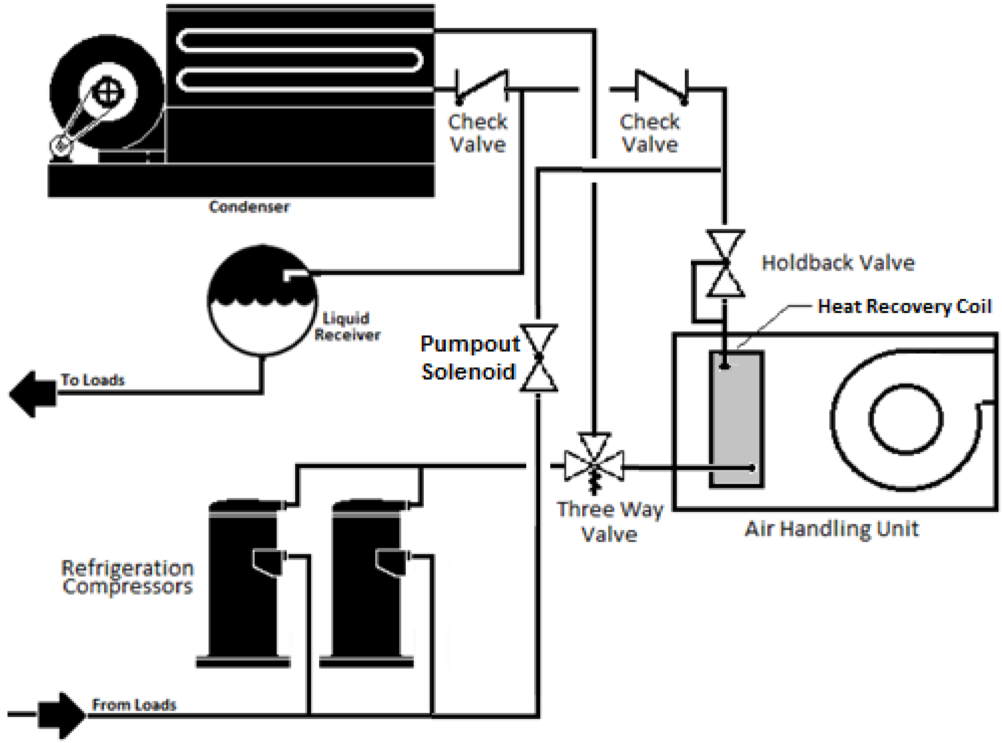


Figure 10-16 shows a parallel-connected direct-condensing configuration. In this configuration, the heat recovery coil handles the entire condensing load for the connected refrigeration system(s) when the air-handling unit is in heating mode. Reduced refrigerant charge is the primary advantage of this configuration. Since the unused condenser (either the heat recovery condenser or the outdoor condenser) can be pumped out, there is no increase in refrigerant charge. A high degree of design expertise is required with this configuration in that the heat recovery condenser and associated HVAC system must take the entire heating load while operating at reasonable condensing temperatures — in any event, no higher than the system design SCT and in most instances with reasonable design no higher than 95°F-100°F condensing temperature in the heat recovery condenser. Ducting with under case or low return air design is essential in this type of system to obtain cooler entering air and maintain reasonable condensing temperatures. Provision is required for practical factors such as dirty air filters.

Since the main condenser is not in use during heat recovery, the condenser floating head pressure requirements do not apply.

Figure 10-16: Parallel Direct Condensing Heat Recovery Configuration

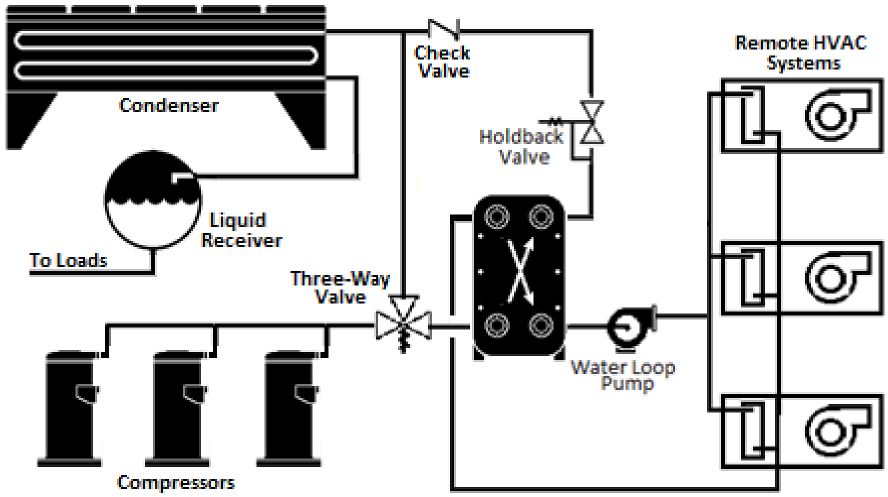


B. Indirect Heat Recovery

Figure 10-17 shows an indirect heat recovery configuration with a fluid loop. In this configuration, the recovered heat is transferred from the refrigerant to an intermediate fluid, normally water or water-glycol, which is circulated through a fluid-to-air heat exchanger located in the air-handling unit airstream. Like the direct condensing configuration, discharge refrigerant gas from the compressors is routed through the refrigerant-to-fluid heat exchanger and then to the outdoor refrigerant condenser when in heating mode.

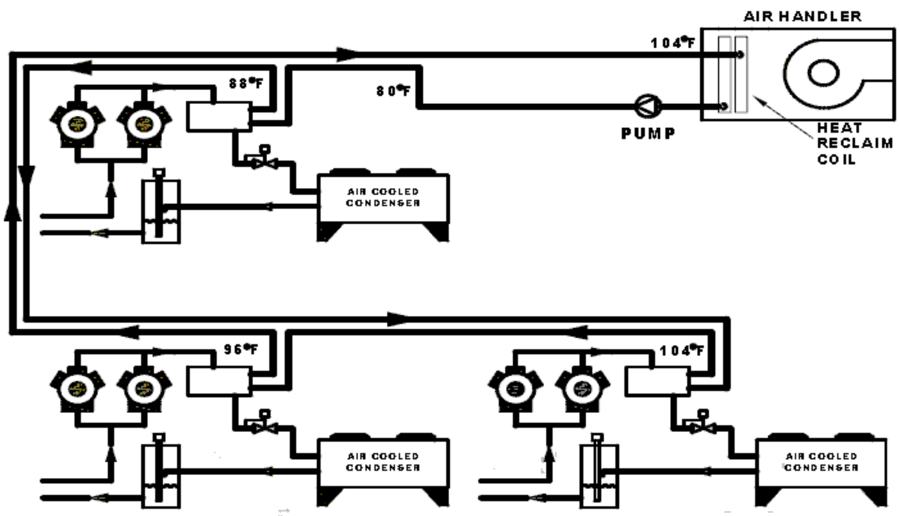
The refrigerant-to-fluid heat exchanger can be located close to the refrigeration system compressors, maximizing the available heat for recovery while keeping the overall refrigerant charge increase low. This configuration is also suitable when multiple HVAC units are employed for the refrigeration heat recovery. Indirect systems must use a circulation pump to circulate the fluid between the HVAC unit and the recovery heat exchanger.

Figure 10-17: Indirect Heat Recovery With an Indirect Loop



Several refrigeration systems can also be connected in parallel or in series, using a common indirect fluid loop. Figure 10-18 shows three refrigeration systems connected in series by a common fluid loop. The temperatures shown are only examples.

Figure 10-18: Series-Piped Indirect Water Recovery



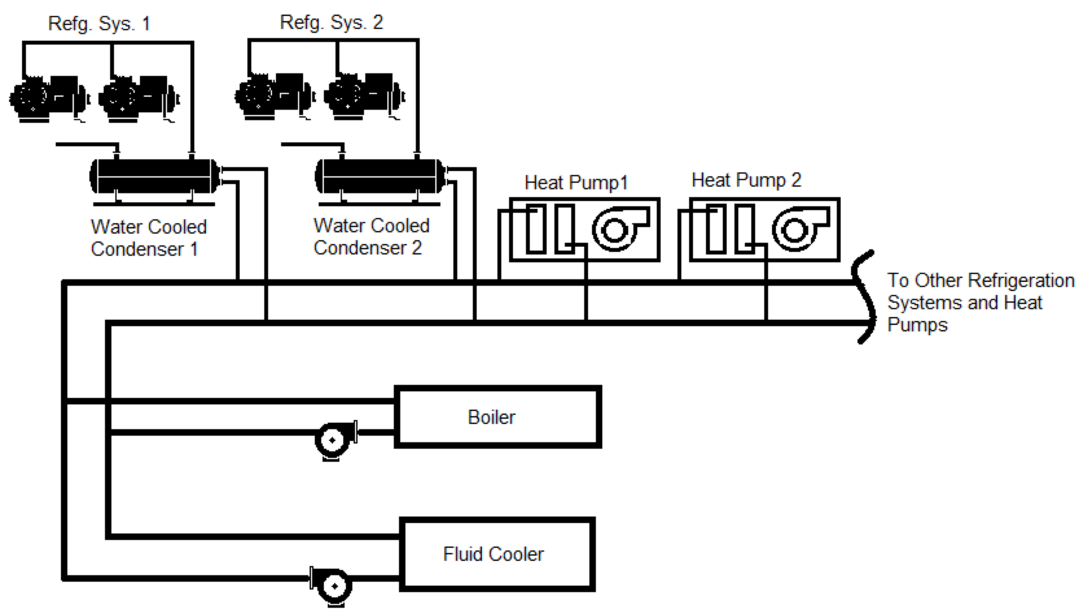
This configuration allows the refrigerant-to-water condenser temperature difference (TD) to be kept low at each refrigeration system (e.g., 8°-10°F is possible) while maintaining a sufficiently high water-side TD at the air-handling unit (e.g., 20°-25°F depending on specifics) to allow an effective selection of the water-to-air heating coil vs. the available airflow. This method also minimizes both the required fluid flow and pump power.

10.5.5.1 Water Loop Heat Pump Heat Recovery

Water-source heat pumps (WLHP) can be used for in conjunction with water cooled refrigeration systems, connected to a common water loop as shown in Figure 10-19. Refrigeration systems heat pumps serving various zones of the store reject heat into a water loop, which in turn is rejected to ambient by an evaporative fluid cooler. When the heat pumps are in heating mode, they extract the heat rejected by the refrigeration systems from the water loop. Additional heat, if required, is provided by a boiler connected to the water loop. A significant advantage of this design is low refrigerant charge, since the refrigeration systems use a compact water-cooled condenser, typically with less charge than an air-cooled condenser and no heat recovery condenser is required. Compared with other methods, however, the electric penalty is somewhat higher to utilize the available heat.

The floating pressure requirements in the standard would apply to the fluid coolers, i.e., controls to allow refrigeration systems to float to 70°F SCT and use of wet bulb following control logic.

Figure 10-19: Water Loop Heat Pump Example

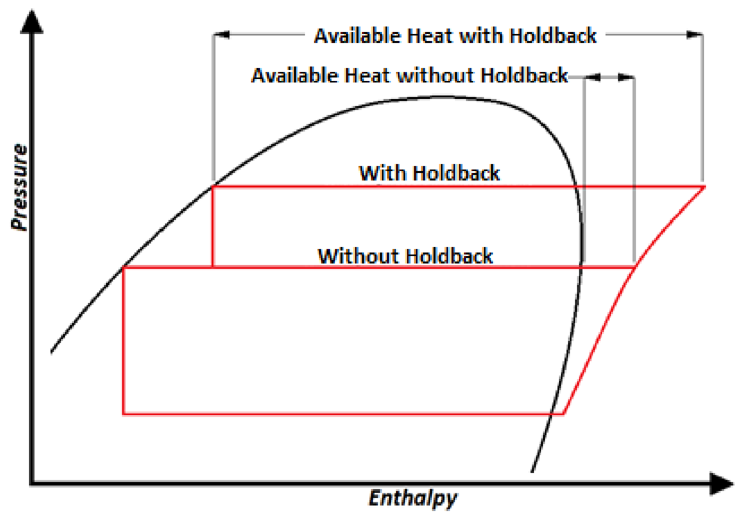


10.5.5.2 Control Considerations

A. Holdback Considerations

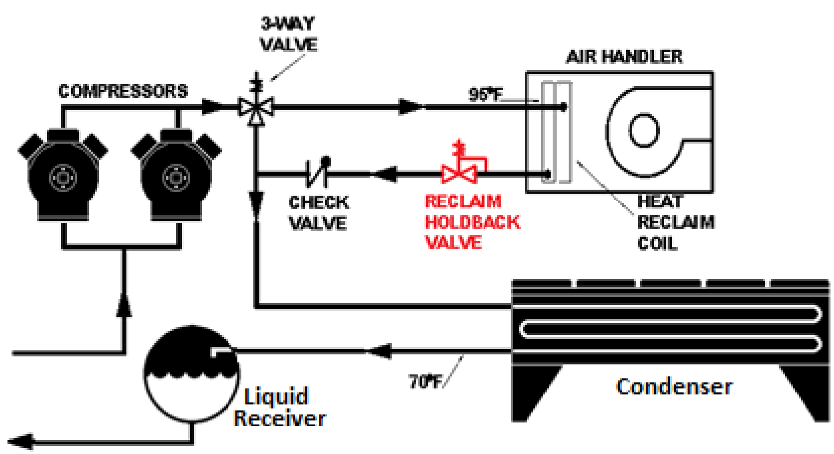
For direct and indirect systems, a holdback valve is required to control the refrigerant condensing temperature in the heat recovery coil (for direct systems) or the refrigerant-to-water condenser (for indirect systems) during heat recovery. Regulating the refrigerant pressure to achieve condensing recovers the latent heat from the refrigerant. Without condensing, only the sensible heat (i.e., superheat) is obtained, which is only a small fraction of the available heat. Figure 10-20 is a pressure-enthalpy diagram showing the difference in available recovery heat from a refrigeration system with and without a holdback valve.

Figure 10-20: Pressure-Enthalpy Diagram With and Without a Holdback Valve



The holdback valve regulates pressure at the inlet and is at the exit of the recovery heat exchanger. Figure 10-21 shows a direct-condensing configuration with the proper location of the holdback valve.

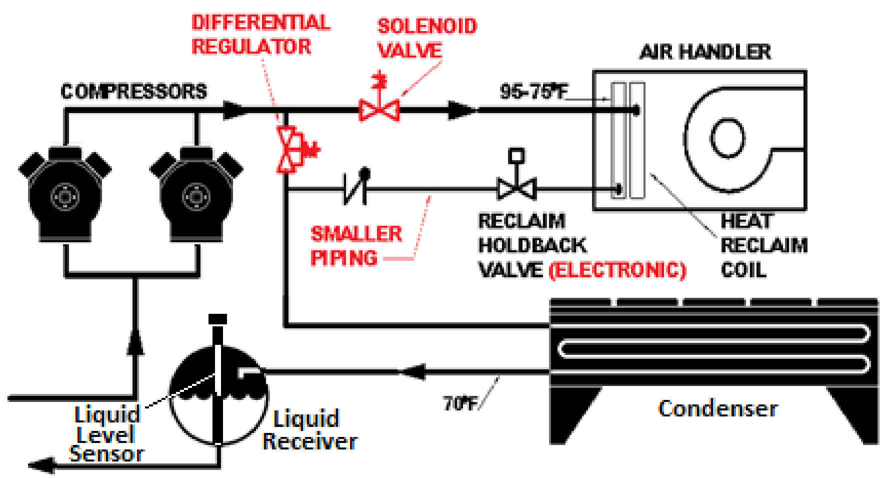
Figure 10-21: Direct-Condensing Configuration Showing Location of Holdback Valve



A more advanced design uses an electronic holdback valve controlled based on the temperature of the air entering the heat recovery coil. The electronic heat recovery holdback valve controls the valve inlet pressure and thus the heat recovery coil condensing temperature to maintain only the pressure necessary to achieve the required condensing TD (heat recovery SCT less entering air temperature), thereby minimizing compressor efficiency penalty. This is particularly useful when the volume outside air can significantly change the mixed air temperature entering the heat recovery coil. In colder climates, reducing the heat recovery holdback pressure can be important as a means to avoid overcondensing (i.e., subcooling). As shown in the pressure-enthalpy diagram above, there is additional flash gas handled by the condenser (even if the refrigerant fully condenses in the heat recovery coil), which is necessary to maintain piping and condenser velocity and, thus, minimize the charge in the outdoor condenser.

Other designs can replace the three-way valve with a differential pressure regulator and solenoid valve. Figure 10-22 shows a direct-condensing configuration with an electronic heat recovery holdback valve, solenoid valve, and differential pressure regulator.

Figure 10-22: Direct-Condensing Configuration Showing Differential Regulator, Solenoid Valve, Electronic Holdback Valve

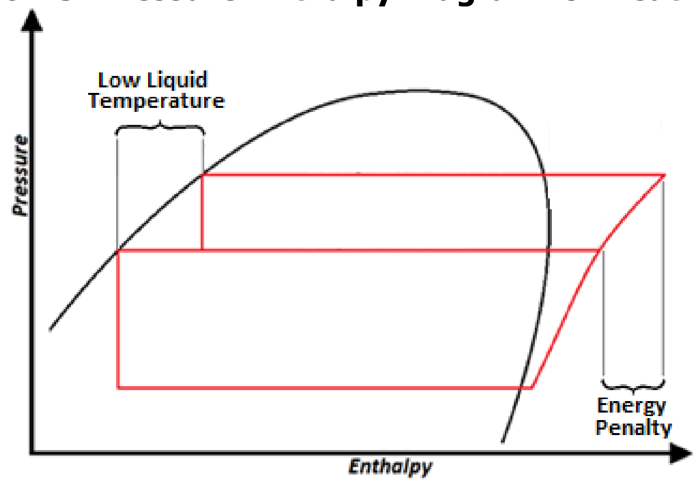


B. Heat Recovery and Floating Head Pressure

There is typically a tradeoff between heat recovery and refrigeration system efficiency, in that compressor discharge pressure must be increased to provide condensing for heat recovery. If implemented properly, the electric penalty at the refrigeration system compressors is small compared to the heating energy savings.

The Energy Codes require that the minimum condensing temperature at the refrigeration condenser shall be 70°F or less. That means that (in the typical case of series-connected heat recovery) the refrigeration “cycle” still benefits from lower refrigerant liquid temperature, even if the compressor power is somewhat increased during heat recovery. The pressure-enthalpy diagram shown in Figure 10-23 shows the incremental energy penalty at the refrigeration compressors due to the higher discharge pressure required for heat recovery, as well as the lower liquid temperature (and thus improved refrigerant cooling capacity) by floating head pressure at the outdoor condenser.

Figure 10-23: Pressure-Enthalpy Diagram for Heat Recovery



10.5.5.3 Recovery Coil Design Considerations

A. Recovery Coil Sizing Example

Selecting an appropriately sized heat recovery coil is essential to proper heat recovery system operation. The following example details the process of selecting a right-sized heat recovery coil.

Example 10-23

Question:

A supermarket is being constructed that will use heat recovery. The refrigeration system selected for recovery has the following parameters:

Design refrigeration load: 455.8 MBH

System design SST: 24°F

Representative compressor capacity at design conditions: 54.2 MBH

Representative compressor power at design conditions: 5.59 kW

The HVAC system serving the supermarket sales area is a central air-handling unit. Heat recovery will be accomplished with a direct-condensing recovery coil inside the air-handling unit, downstream of both the return air duct and the outside air damper. The air-handling unit has the following design parameters:

Design air volume: 25,000 cfm

Design coil face area: 41.7 ft2

To avoid excessive pressure, drop across the recovery coil, the designer will select a coil with a fin density of 10 fins per inch. The heat recovery circuit will use a holdback valve set at 95°F SCT.

What is the procedure for selecting a heat recovery coil?

Answer:

To size a heat recovery system, the designer should first establish a design recovery coil capacity by analyzing the refrigeration system from which heat will be recovered. Best practice dictates that the recovery system should be sized to recover most of the available system total heat of rejection at typical operating conditions, not peak conditions. Since we are designing for average operating conditions, the designer assumes the average refrigeration load is 70% of the design load. Therefore, the average system THR for heating design is:

Average System THR = 70% x Design Refrigeration Load x THR Adjustment Factor

where:

$$\text{THR Adjustments Factor} = \frac{\text{Representative Compressor THR}}{\text{Representative Compressor Capacity}}$$

and:

Rep. Compressor THR = Rep. Compressor Capacity + Rep. Compressor Heat of Compression

Using values from the example:

$$\text{Representative Compressor THR} = 54.2\text{MBH} + \left(5.50\ \text{kW} \times \frac{3.415\ \text{MBH}}{\text{kW}}\right)$$

Representative Compressor THR = 73.3 MBH

Therefore,

$$\text{THR Adjustment Factor} = \frac{73.3\ \text{MBH}}{54.2\ \text{MBH}}$$

THR Adjustment Factor = 1.35

Using the values in this example and the calculated THR adjustment factor, the average system THR is:

Average system THR = 70% x 455.8 MBH x1.35

Average system THR = 430.1 MBH

The recovery system will not be capable of extracting 100% of the total heat of rejection since the condenser operates at a lower pressure and will reject additional heat, even if the heat recovery coil achieves full condensing. In addition, the heat recovery coil performance may often be limited by the available airflow across the coil and the consequent temperature rise vs. the heat being transferred. This performance is determined through evaluation of coil performance, considering entering air temperature, and condensing temperature, as well as the coil design (e.g., rows, fins, air velocity and other factors). Airside pressure drop can be minimized by using a larger face area, requiring lower face velocity and fewer rows.

For in this example, it was assumed that after evaluating coil performance, 85% of the average THR could be recovered with a reasonable coil velocity and coil depth.

Available Heat for Reclaim = 85% x Average System THR

Available Heat for Reclaim = 85% x 430.1 MBH

Available heat for Reclaim = 365.6 MBH

The available heat for recovery is the design capacity of the recovery coil we will select for our air-handling unit.

Next, the designer needs to know the face velocity of the airstream in the air-handling unit. The face velocity is:

$$F.V. = \frac{\text{Design cfm}}{\text{AHU Face Area}}$$

$$F.V. = \frac{25{,}000 \text{ cfm}}{41.7 \text{ ft2}}$$

F.V. = 600 ft/min

Finally, the designer needs to know the temperature difference between the condensing temperature (inside the recovery coil) and the temperature of the air entering the recovery coil. Since the coil will be installed in an air-handling unit downstream of the outside air damper, the designer assumes that the air entering the coil is a mix of return air from the store and outside air. The designer must determine an appropriate design temperature for the air entering the recovery coil (entering air temperature or EAT) during average heating hours, which in this instance was determined to be 65°F. From the example, the heat recovery system will have a holdback valve setting of 95°F SCT. Therefore, the temperature difference is:

TD = SCT – EAT

TD = 95oF - 65oF

TD = 30oF

Using the face velocity, design coil capacity, and temperature difference between condensing temperature and entering air temperature, the designer then refers to the air-handling unit catalog to select a recovery coil. Then the designer uses the following two tables:

Heat reclaim correction factor for temperature difference between air and refrigerant.

Temperature Difference (°F)	20	25	30	35	40	45	50	60
Correction Factor	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2

Hot Gas Reclaim Heating Capacities
MBH per SQ FT of coil face area

Rows	FPI	Face Velocity (ft/min)		
		500	550	600
2	8	10.9	11.38	11.85
	10	12.15	12.73	13.18
	12	13.13	13.77	14.35
3	8	14.56	15.25	15.9
	10	15.93	16.8	17.63
	12	17.08	18.03	18.95
4	8	17.43	18.47	19.47
	10	18.75	19.92	21.07
	12	19.98	21.25	22.5

The designer enters the first table with the calculated TD of 30°F, finding a correction factor of 0.6. We enter the second table with the value:

MBH per SQ FT = (Design Coil Capacity) / Correction Factor
Coil Face Area

MBH per SQ FT = (4184 MBH) / 0.6
41.7 ft²

MBH per SQ FT = 16.72

Per design requirements, the designer will select a 10-fin-per-inch coil. From the second table, the designer selects the three-row, 10-fin-per-inch coil for this application.

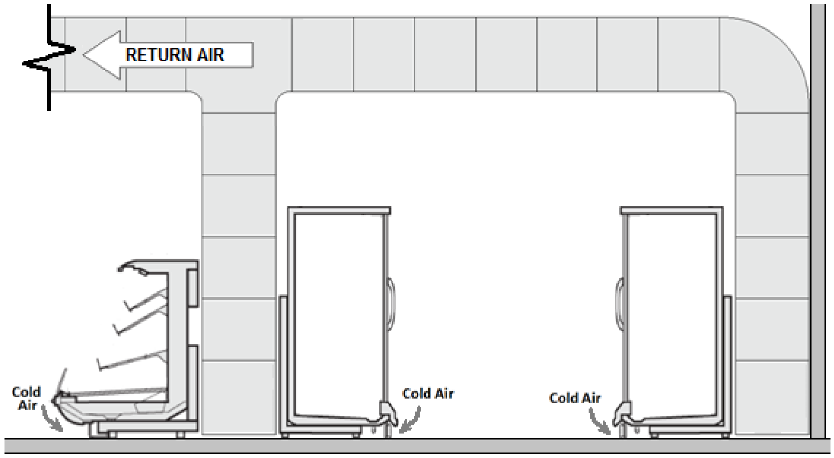
More commonly, computerized selection tools are used to select heat recovery coils, allowing vendors to provide multiple selections for comparison.

B. Air-Side Integration Considerations

1. Return Air Location

In supermarkets, ducting return air from behind display cases or near the floor is beneficial in improving comfort by removing the stagnant cool air that naturally occurs due to product refrigeration cases. This approach also increases the effectiveness of refrigeration heat recovery by increasing the temperature difference between the return air temperature and the refrigerant condensing temperature in the heat recovery coil. Figure 10-24 shows the location of an HVAC return air duct positioned to scavenge cool air from the floor level near refrigerated display cases.

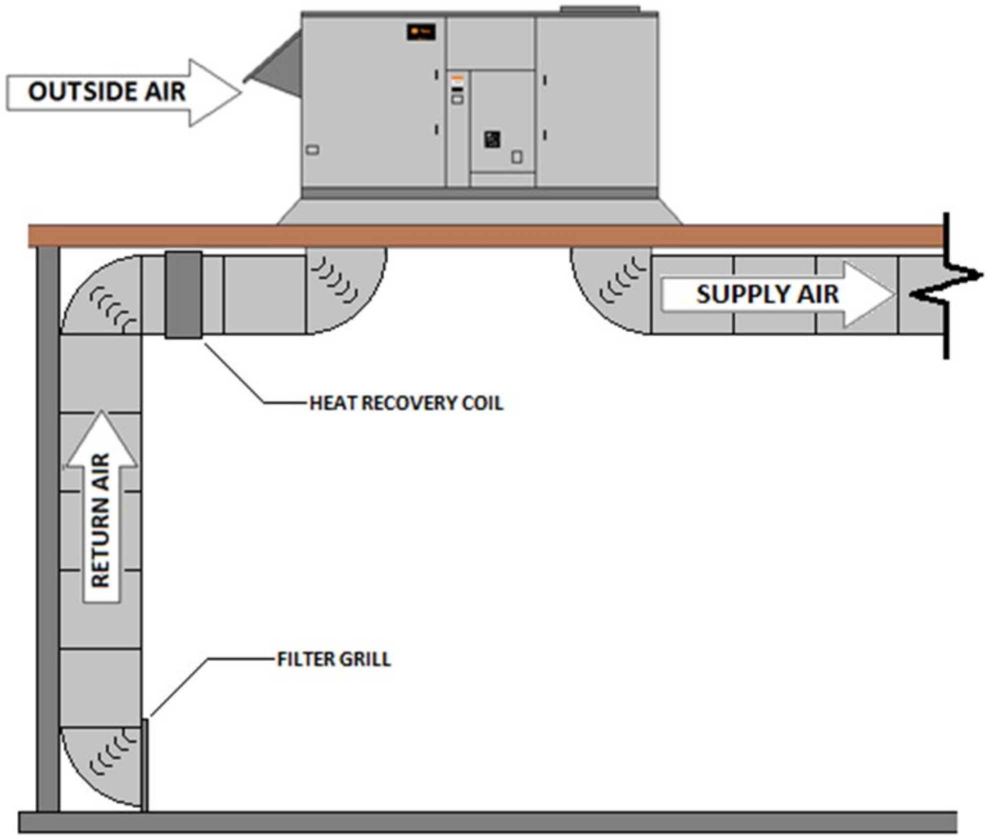
Figure 10--24: Low Return Air Example



2. Return Air Duct Configuration

Heat recovery can be incorporated into rooftop HVAC units (RTU) by installing the heat recovery coil inside the RTU cabinet or by installing in the return air duct upstream of the RTU, as shown in Figure 10-25. Location inside the RTU is preferable when outside air is a substantial part of the heating load, but location in the return air duct is reasonable and can provide greater flexibility in selecting the heat recovery coil (e.g., for low face velocity and pressure drop), particularly when coupled with low return air on units in the refrigerated space, which predominantly provide heating. The fan design must allow for the additional ductwork and coil pressure drop.

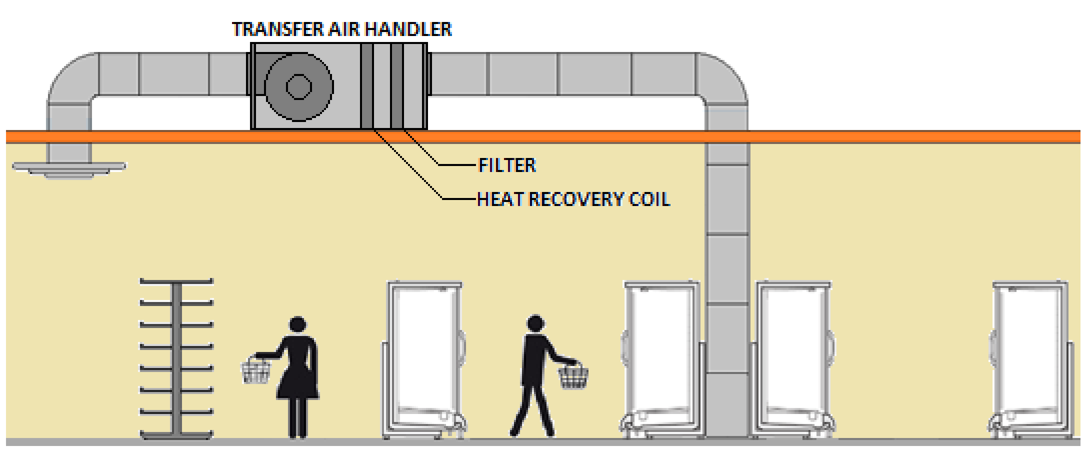
Figure 10-25: Heat Recovery Coil in Return Air Duct



3. Transfer Fan Configuration

A ducted transfer system is sometimes employed to remove cold air from aisles with refrigerated display cases (rather than blowing warm air into the refrigerated areas) and can be an easy and appropriate way to use heat recovery, particularly from smaller distributed systems. Figure 10-26 depicts a ducted transfer system.

Figure 10-26: Ducted Transfer System



4. Calculating Charge Increase

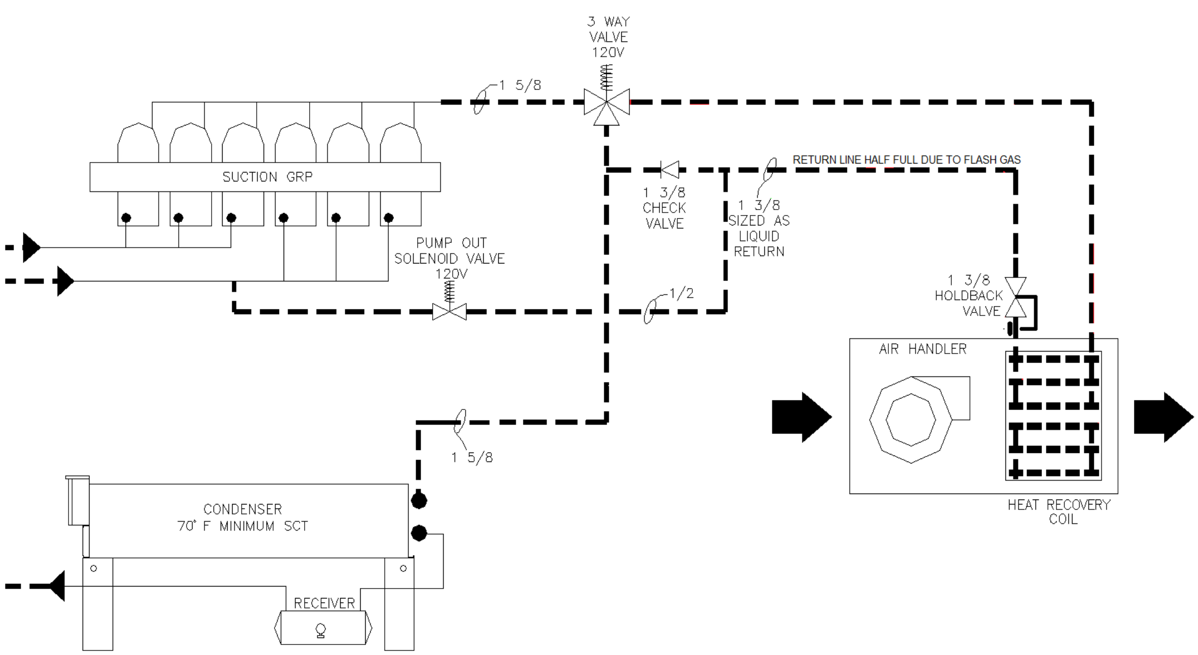
The Energy Code requires that the increase in HFC refrigerant charge from all equipment related to heat recovery for space heating shall be less than 0.35 lbs. for every 1,000 Btuh of heat recovery capacity at design conditions. Refrigerant charge may increase because of the addition of the recovery coil itself (either the refrigerant-to-air heat exchanger for direct configurations, or the refrigerant-to-water heat exchanger for indirect configurations) and the additional piping between the compressor group and the recovery coil. In addition, the refrigerant leaving the recovery coil and entering the refrigerant condenser will be mostly condensed, which increases the charge in the outdoor condenser compared with normal operation. Operating the outdoor condenser at lower pressure (i.e., the required floating heat pressure control) vs. the higher setting at the heat recovery coil holdback valve creates pressure drop, flashing of some liquid to vapor and an increase in velocity due to the much larger volume of a pound of vapor vs. a point of liquid refrigerant. Split condenser control, which is very common in cooler climates, can also be used to close off and pump out half of the outdoor condenser.

It is the responsibility of the system designer to fully understand how the heat recovery system affects overall refrigerant charge.

Example 10-24

Question:

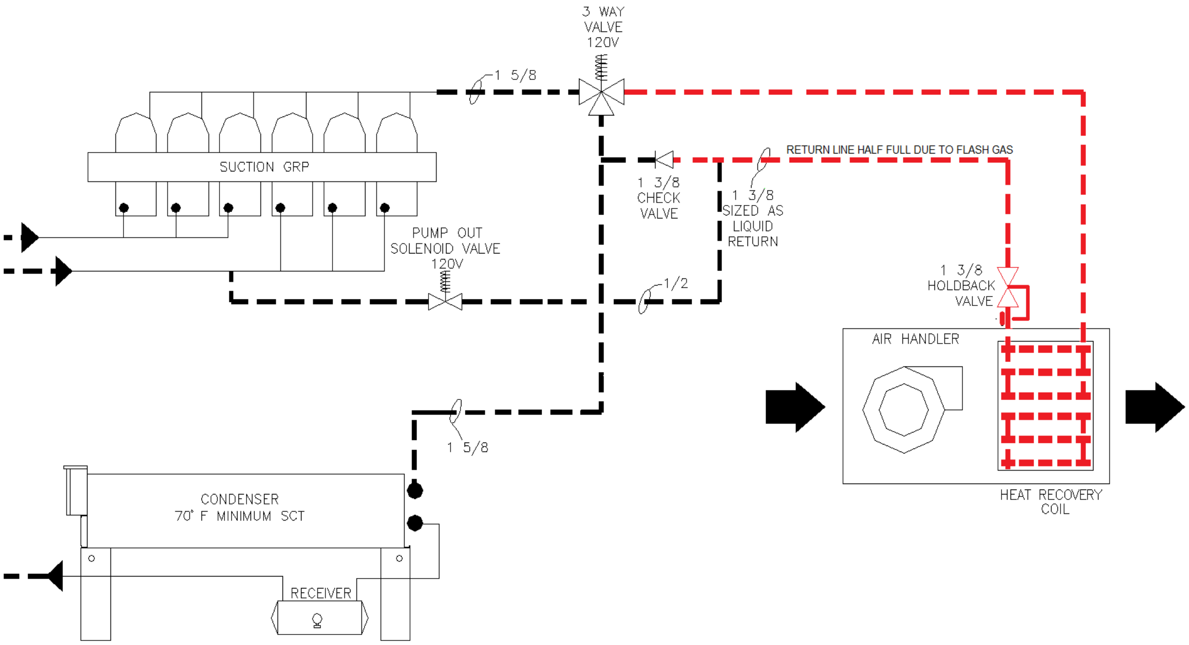
A heat recovery system is being designed for a new supermarket. The refrigerant is R-404A. The proposed design is shown below:



Which piping runs should be included in the calculation of refrigerant charge increase in the proposed design?

Answer:

Only the additional piping required to route the refrigerant to the heat recovery coil needs to be considered in this calculation. The piping runs shown in red in the following figure should be included in the calculation of refrigerant charge increase from heat recovery.



Example 10-25

Question:

What is the refrigerant charge size increase in the example described above?

Answer:

The system designer prepares the following analysis to calculate the charge size in the refrigerant piping.

	Saturation Temperature (°F)	Pipe OD (in)	Pipe ID (in)	Pipe Length (ft)	Line Volume (ft^3)	% Vapor, Liquid by Mass	% Vapor, Liquid by Volume	Refrigerant Charge (lbs)
Discharge Line to Reclaim Coil	95	1 5/8	1 1/2	100	1.2	100%, 0%	100%, 0%	6.7
Liquid/Vapor Return Line	80	1 3/8	1 1/4	100	0.9	9%, 91%	59%, 41%	25.5
							Total Charge:	32.2

The outdoor condenser has a capacity of 350 MBH at a TD of 10°F. Using the manufacturer's published data, the designer determines that the condenser normal operating charge (without heat recovery) is 26.9 lbs. To calculate the charge, increase in the condenser due to heat reclaim, the designer estimates the condenser could be as much as 75% full of liquid, resulting in a condenser charge of 68.8 lbs. with heat recovery.

The heat recovery coil has a capacity of 320 MBH at a design TD of 20°F. The system designer uses manufacturer's documentation to determine that the heat recovery coil refrigerant charge is 14.1 lbs.

The total refrigerant charge with heat recovery is:

32.2 lbs (piping) + 68.8 lbs (system condenser) + 14.1 lbs (recovery coil) = 115.1 lbs

Therefore, the refrigerant charge increase with heat recovery is: 115.1 lbs – 26.9 lbs = 88.2 lbs

Example 10-26

Question:

In the example above, does the recovery design comply with the requirement in the Energy Code that the recovery design shall use at least 25% of the design total heat of rejection (THR) of the refrigeration system?

Answer:

The system designer determines that the total THR of all the refrigeration systems in the new supermarket is 800 MBH. From the previous example, the heat recovery capacity is 320 MBH.

$$100\ \% \times \frac{320\ \text{MBH}}{800\ \text{MBH}} = 40\%$$

Therefore, the design complies with the Energy Code.

Example 10-27

Question:

In the example above, does the recovery design comply with the requirement in the Energy Code that the recovery design shall not increase the refrigerant charge size by more than 0.35 lbs. of refrigerant per 1,000 Btuh of recovery capacity?

Answer

From the previous example, the recovery capacity is 320 MBH at design conditions, and the total refrigerant charge size increase is 88.2 lbs.

<u>88.2 lbs</u> = 0.28 lbs/Btuh
320 MBH

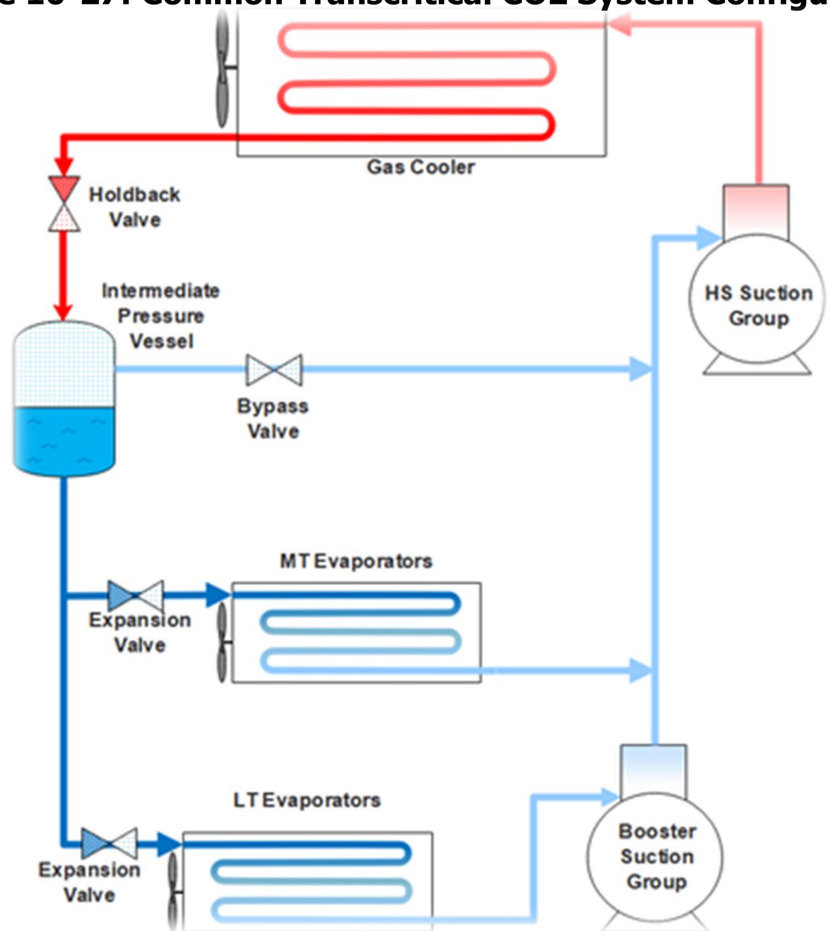
Since the refrigerant charge increases by less than 0.35 lbs/MBH, this design complies with the Energy Code.

10.5.6 Transcritical CO_2 Systems

§120.6(b)5

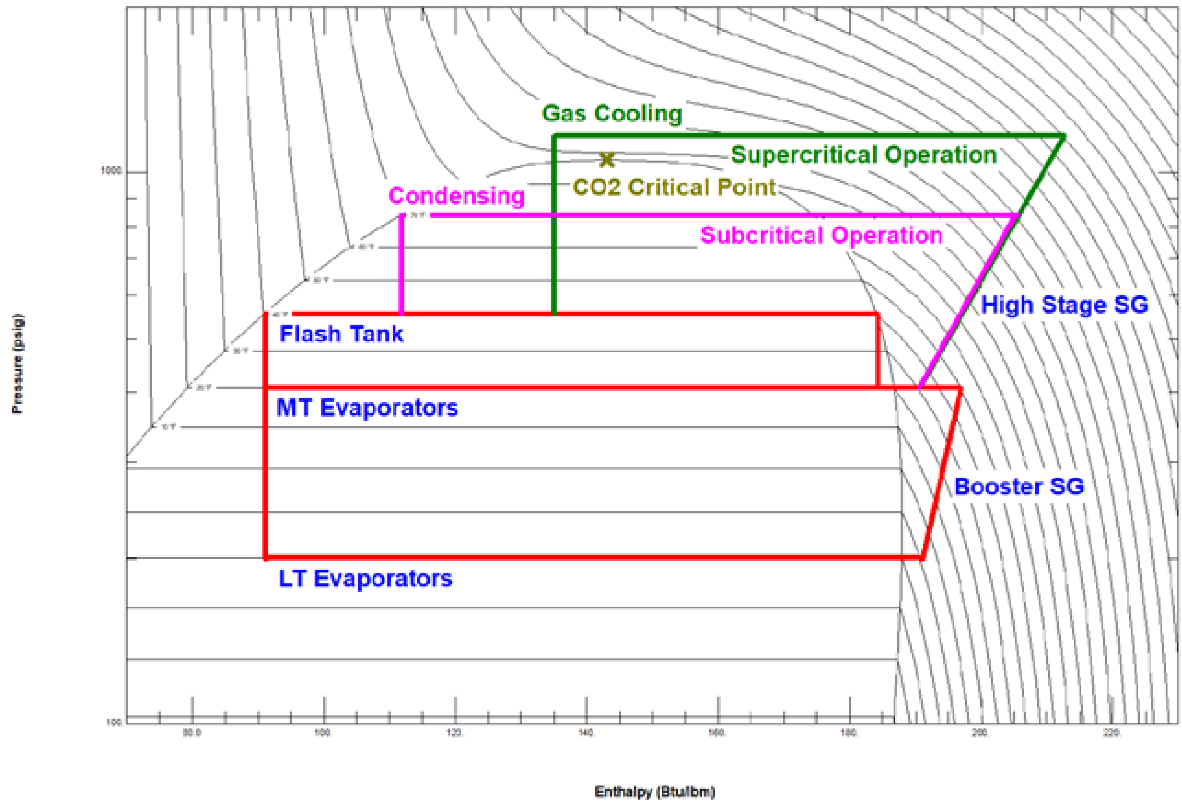
A typical transcritical CO_2 booster system is shown in Figure 10-27 below. The system consists of two suction groups: booster and high stage (HS). The compressors in the booster suction group serve low temperature (LT) loads and discharge into the suction of the high stage suction group. The compressors in the high stage suction group serve the medium temperature (MT) loads, as well as compress the gas from the booster suction group and the intermediate pressure vessel to high pressures. Heat is rejected from the high pressure gas in the gas cooler when the system is operating in supercritical mode. The discharge pressure is commonly controlled by a hold back valve in combination with the gas cooler fans. When operating in subcritical mode the gas cooler operates as a condenser, analogous to other common refrigeration systems. The gas or liquid from the gas cooler/condenser expands in the intermediate pressure vessel/flash tank. The gas from the intermediate pressure vessel is compressed by the high stage compressors, and the liquid from the flash tank is supplied to medium temperature and low temperature evaporators (loads). The evaporated gas in the evaporators is compressed by its respective suction group compressors.

Figure 10-27: Common Transcritical CO2 System Configuration



The critical point of a substance is the point above which the liquid and vapor phases become indistinguishable from each other, forming a "supercritical fluid." In the supercritical region, temperature and pressure are semi-independent variables. CO_2 has a critical point of 87.8°F, which is considered to be a low critical point compared to all commonly used refrigerants. A pressure-enthalpy (PH) diagram for CO_2 with its critical point labeled is shown in Figure 10-28. In a transcritical CO_2 refrigeration system, the high-stage suction group can operate both above and below the critical point. When ambient temperatures are high, above approximately 75°F, the HS suction group compresses CO_2 above its critical point and the system is said to be in supercritical operation. An example of a HS suction group supercritical vapor compression cycle on the PH diagram for CO_2 is represented in green in Figure 10-28. During lower ambient conditions, when CO_2 is below its critical point after compression, the system is said to be in subcritical operation. An example of a HS suction group subcritical vapor compression cycle on the PH diagram for CO_2 is represented in pink in Figure 10-28.

Figure 10-28: Pressure-Enthalpy CO2 Diagram With Transcritical Vapor Compression Cycle (Diagram Created Using REFPROP – NIST Reference Fluid Properties)



In subcritical mode, the system operates very similarly to other refrigeration systems. In supercritical mode, the overall system efficiency decreases compared with subcritical operation. This is because high ambient temperatures result in higher compressor discharge temperatures needed for heat rejection, which increases the suction-to-discharge pressure ratio to be overcome by the compressor. Additionally, when operating in supercritical mode, the gas cooler outlet stream has a higher quality (higher vapor fraction) compared to subcritical mode. Vapor in the intermediate pressure vessel does not contribute to productive refrigeration but needs to be compressed, increasing the nonproductive refrigeration load on the compressors. Available technologies that increase supercritical operation efficiency include gas ejectors and parallel compression.

10.6.1.1 Transcritical CO_2 Gas Coolers

§120.6(b)5

New fan-powered gas coolers on all new transcritical CO_2 refrigeration systems must follow the gas cooler type, sizing, fan control, and efficiency requirements as described in §120.6(b)5.

10.5.6.1 Air-Cooled Gas Coolers Restrictions

§120.6(b)5A

Section 120.6(b)5A prohibits the use of air-cooled gas coolers in Climate Zones 10 through 15, which are high ambient temperature climate zones, to reduce the number of supercritical operating hours. Alternatives to air cooled gas coolers include water cooled gas coolers connected to a cooling tower, adiabatic gas coolers, and evaporative gas coolers.

10.5.6.2 Gas Cooler Sizing

Section 120.6(b)5B and §120.6(b)5C describe minimum sizing requirements for new gas coolers serving new transcritical CO_2 refrigeration systems. Fan-powered air-cooled gas coolers are covered by §120.6(b)5B. Fan-powered adiabatic gas coolers are covered by §120.6(b)5C.

Gas coolers must be sized to provide sufficient heat rejection capacity under design conditions while maintaining a specified maximum temperature difference between the gas cooler leaving gas temperature and ambient temperature. The design gas cooler capacity shall be greater than the calculated combined total heat of rejection (THR) of the dedicated compressors that are served by the gas cooler. If multiple gas coolers are specified, then the combined capacity of the installed gas coolers shall be greater than the calculated heat of rejection. When determining the design THR for this requirement, reserve or backup compressors may be excluded from the calculations. Example 10-42 provides an example scenario of which compressors to include in the THR calculation described in this section.

10.5.6.3 Air-Cooled Gas Cooler Sizing

§120.6(b)5B

Section 120.6(b)5B provides maximum design gas cooler leaving gas temperature (LGT) values for air-cooled gas coolers. For this section, designers should use the 0.5 percent design dry bulb temperature (DBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement.

Standard practice is for published gas cooler ratings to assume the capacity of air-cooled gas coolers is proportional to the temperature difference (TD) between the LGT and DBT, regardless of the actual ambient temperature entering the gas cooler. For example, the capacity of an air-cooled gas cooler operating at a leaving gas temperature of 80°F with a DBT of 70°F is assumed to be equal to the same unit operating at 110°F LGT and 100°F DBT, since the TD across the gas cooler is 10°F in both examples. Thus, the requirement for air-cooled gas coolers is based on the temperature difference between the DBT and gas cooler leaving gas temperature. Air cooled gas coolers shall be sized so the design leaving gas temperature for air-cooled gas coolers shall be less than or equal to the design dry bulb temperature plus 6°F.

10.5.6.4 Adiabatic Gas Cooler Sizing

§120.6(b)5C

Section 120.6(b)5C provides maximum design gas cooler leaving gas temperature (LGT) values for adiabatic gas coolers. For this section, designers should use the 0.5 percent design dry bulb temperature (DBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement.

Standard practice is for published gas cooler ratings to assume the capacity of adiabatic gas coolers is proportional to the temperature difference (TD) between the LGT and DBT for operation in dry mode, regardless of the actual ambient temperature entering the gas cooler. For example, the capacity of an adiabatic gas cooler operating at a LGT of 80°F with a DBT of 70°F is assumed to be equal to the same unit operating at 110°F LGT and 100°F DBT during dry mode operation, since the TD across the gas cooler is 10°F in both examples. Thus, similar to air-cooled gas coolers, the requirement for adiabatic gas coolers is based on the temperature difference between the DBT and gas cooler leaving gas temperature. Design leaving gas temperature for adiabatic gas coolers necessary to reject the design total heat of rejection of a refrigeration system assuming dry mode performance shall be less than or equal to the design dry bulb temperature plus 15°F.

10.5.6.5 Fan Control

Section 120.6(b)5D through §120.6(b)5G describe fan control requirements for new gas coolers serving new transcritical CO_2 refrigeration systems. Fan speed control requirements are covered by §120.6(b)5D. Gas cooler pressure control requirements during subcritical and supercritical operation are described by §120.6(b)5E and §120.6(b)5F, respectively. Minimum condensing temperature set point is covered by §120.6(b)5G.

10.5.6.6 Speed Control

§120.6(b)5D

Gas cooler fans for new air-cooled, evaporatively cooled or adiabatic gas coolers, or fans on cooling towers or fluid coolers used to reject heat on new transcritical CO_2 refrigeration systems, must use continuously variable speed. Variable-frequency drives are commonly used to provide continuously variable-speed control of gas cooler fans, although controllers designed to vary the speed of electronically commutated motors may be used to control these types of motors. All fans serving a common high side, or cooling water loop for cooling towers and fluid coolers, shall be controlled in unison. Thus, in normal operation, the fan speed of all fans within a single gas cooler or set of gas coolers serving a common high side should modulate together, rather than running fans at different speeds or staging fans off. However, when fan speed is at the minimum practical level usually no higher than 10–20%, the fans may be staged off to reduce gas cooler capacity. As load increases, fans should be turned back on before significantly increasing fan speed, recognizing a control band is necessary to avoid excessive fan cycling.

10.5.6.7 Subcritical Pressure Control

§120.6(b)5E

Section 120.6(b)5E provides pressure control requirements for gas cooler operation below the critical point. These requirements are the same as for §120.6(b)1A with the exception that the minimum condensing temperature set point must be 60°F for transcritical CO_2 systems with a design intermediate saturated suction temperature lower than 30°F. See Section 10.4.2.1 for details.

10.5.6.8 Supercritical Pressure Control

§120.6(b)5F

During supercritical mode, the gas cooler pressure set point must be continuously reset in response to ambient conditions to optimize system efficiency, rather than using a fixed set point value.

Specifying the exact relationship to be used to determine the optimal head pressure may depend on several variables beyond ambient air temperature, including the operating saturated suction temperature, system configuration, gas cooler technology type, and current load. The controls manufacturer shall consider the tradeoff between fan energy and compressor energy in developing a pressure and fan control that is responsive to environmental and system conditions.

10.6.1.1.3.4. Minimum SCT Set point

§120.6(b)5G

The minimum saturated condensing temperature set point must be 60°F (16°C) or less for air-cooled gas coolers, evaporative-cooled gas coolers, adiabatic gas coolers, air or water-cooled fluid coolers or cooling towers. As a practical matter, a maximum condensing temperature set point is also commonly employed to set an upper bound on the control set point in the event of a sensor failure and to force full gas cooler operation during peak ambient conditions. This value should be set high enough that it does not interfere with normal operation.

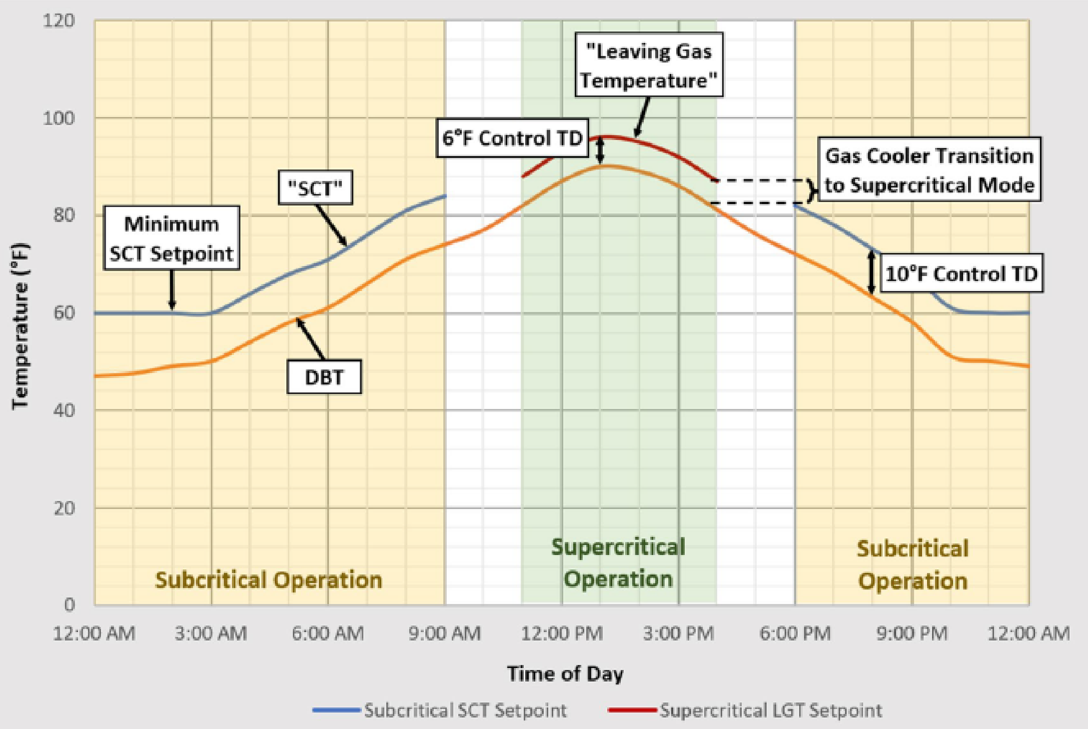
Example 10-27

Question

A commercial refrigeration facility with air-cooled gas coolers serving freezers is being commissioned. The control system designer has used a drybulb-following control strategy to reset the system saturated condensing temperature (SCT) setpoint when the system is operating subcritically, and has used a TD of 10°F (5.6°C) above the ambient drybulb temperature. The control system designer has used a proprietary gas cooler pressure control strategy to maximize system efficiency by minimizing the combined compressor and condenser fan power usage when the system is operating supercritically, with a TD of 6°F (3.3°C). What might the system DBT and SCT / gas cooler leaving gas temperature (LGT) setpoints trends look like over an example day?

Answer

The following figure illustrates what the actual SCT / LGT setpoint could be over an example day using the drybulb-following control strategy with a 10°F TD (5.6°C) when operating subcritically, a 6°F (3.3°C) TD when operating supercritically and observing the 60°F (16°C) minimum condensing temperature requirement. As the figure shows, the SCT setpoint is continuously reset to 10°F (5.6°C) above the ambient drybulb temperature until the minimum SCT setpoint of 60°F (16°C) is reached when operating subcritically and 6°F (3.3°C) above the ambient drybulb temperature when operating supercritically.



10.5.6.9 Gas Cooler-Specific Efficiency

§120.6(b)5H

Requirements for design leaving gas temperatures relative to design ambient temperatures, as described above for §120.6(b)5B and C, help assure that there is enough gas cooler capacity to keep leaving gas temperatures compressor head pressures at reasonable levels. However, the sizing requirements do not address gas cooler efficiency. For example, rather than providing amply sized gas cooler surface area, a gas cooler selection could consist of a small gas cooler area using a large motor to blow a large amount of air through the heat exchanger surface to achieve the design gas cooler TD. However, this would come at the expense of excessive fan motor horsepower. Also, relatively high fan power consumption can result from using gas cooler fans that have poor fan efficiency or low fan motor efficiency. Section 120.6(b)5H addresses these and other factors affecting gas cooler fan power by setting minimum specific efficiency requirements for gas coolers.

Table 10-6: Transcritical CO_2 Fan-Powered Gas Coolers — Minimum Specific Efficiency Requirements

Condenser Type	Refrigerant Type	Minimum Specific Efficiency	Rating Condition
Outdoor Air-Cooled	Transcritical CO_2	160 Btuh/Watt	1400 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature
Adiabatic Dry Mode	Transcritical CO_2	90 Btuh/Watt	1100 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature

Condenser specific efficiency is defined as:

Condenser Specific Efficiency = Total Heat Rejection(THR) Capacity / Input Power

The total heat rejection capacity is at the rating conditions of 100°F outlet gas temperature and 90°F outdoor dry bulb temperature. Input power is the electric input power draw of the gas cooler fan motors (at full speed). The motor power is the manufacturer's published applied power for the subject equipment, which is not necessarily equal to the motor nameplate rating. Power input for secondary devices shall not be included in the specific efficiency calculation.

As shown in Table 10-6 the Energy Codes have different minimum efficiencies depending on the type of gas cooler that is being used. The different classifications of gas coolers are:

- Outdoor, air-cooled.
- Adiabatic (dry-mode operation).

The data published in the gas cooler manufacturer's published rating for capacity and power shall be used to calculate specific efficiency.

For air-cooled and adiabatic gas coolers, manufacturers typically provide the capacity at a given temperature difference (TDR) between SCT and dry bulb temperature. Manufacturers typically assume that gas cooler capacity is linearly proportional to TD; the catalog capacity at 20°F TD is typically twice as much as at 10°F TD. The gas cooler capacity for air-cooled gas cooler at a TD of 10°F shall be used to calculate specific efficiency. For adiabatic gas coolers, the dry mode capacity at a TD of 10°F shall be used to calculate efficiency. If the capacity at 10°F TD is not provided, the capacity shall be scaled linearly.

Depending on the type of gas cooler, the actual manufacturer's rated motor power may vary from motor nameplate in different ways. Air-cooled gas coolers with direct-drive OEM motors may use far greater input power than the nominal motor horsepower would indicate. Thus, actual motor input power from the manufacturer must be used for direct-drive, air-cooled gas coolers.

Example 10-48 provides an example calculation for the efficiency of a condenser, which is analogous to how the efficiency for a gas cooler would be calculated.

10.5.7 Additions and Alterations

§141.1(b)

The specific requirements for additions and alterations for commercial refrigeration are included in §120.6(b).

10.6 Refrigerated Warehouses

10.6.1 Overview

This section of the manual focuses on the Energy Code provisions unique to refrigerated warehouses. The Energy Code described in this chapter of the manual address refrigerated space insulation levels, underslab heating requirements in freezers, infiltration barriers, evaporator fan controls, condenser sizing and efficiency requirements, condenser fan controls, and screw compressor variable-speed requirements.

All buildings regulated under Part 6 of the Energy Code must also comply with the general provisions of the Energy Code (§100.0–§100.2, §110.0–§110.10, §120.0–§120.9, §130.0–§130.5) and additions and alterations requirements (§141.1). These topics are generally addressed in Chapter 3 of this manual.

10.6.1.1 Mandatory Measures and Compliance Approaches

The energy efficiency requirements for refrigerated warehouses are all mandatory. There are no prescriptive requirements or performance compliance paths for refrigerated warehouses. Since the provisions are all mandatory, there are no trade-offs allowed between the various requirements. The application must demonstrate compliance with each of the mandatory measures. Exceptions to each mandatory requirement, when applicable, are described in each of the mandatory measure sections below.

10.6.1.2 Scope and Application

§120.6(a)

Section 120.6(a) of the Energy Code addresses the energy efficiency of refrigerated spaces within buildings, including coolers and freezers, as well as the refrigeration equipment that serves those spaces. Coolers are defined as refrigerated spaces designed to operate between 28°F (-2°C) and 55°F (13°C). Freezers are defined as refrigerated spaces designed to operate below 28°F (-2°C). The Energy Code does not address walk-in coolers and freezers, defined as refrigerated spaces less than 3,000 ft^2, as these are covered by the Appliance Efficiency Regulations (Title 20). However, refrigerated warehouses and spaces with a total of 3,000 ft^2 or more and served by a common refrigeration system are covered by the Energy Code and required to comply with §120.6(a).

Furthermore, areas within refrigerated warehouses designed solely for quick chilling or quick freezing of products have some exceptions for evaporators and compressors. Quick chilling and freezing spaces are defined as spaces with a design refrigeration evaporator load of greater than 240 Btu/hr-ft^2 of floor space, which is equivalent to 2 tons per 100 ft^2 of floor space. A space used for quick chilling or freezing and used for refrigerated storage must still meet the requirements of §120.6(a).

The intent of the Energy Code is to regulate storage space, not quick chilling or freezing space or process equipment. Recognizing that there is often a variety of space types and equipment connected to a particular suction group in a refrigerated warehouse, it is not always possible to identify compressor plant equipment that serves the storage space only. It would be outside the intent of the Energy Code to apply the compressor plant requirements to an industrial process that is not covered by the Energy Code simply because a small storage space is also attached to the suction group. Similarly, it would be outside the intent of the Energy Code to exclude a compressor plant connected to a suction group serving a large storage space covered by the Energy Code on the basis of a small process cooler or quick chill space also connected to the same suction group. For compliance, the compressor plant requirements in §120.6(a)5B apply when 80 percent or more of the design refrigeration capacity connected to the suction group is from refrigerated storage space(s). A suction group refers to one or more compressors that are connected to one or more refrigeration loads whose suction inlets share a common suction header or manifold.

A variety of space types and processes may be served by a compressor plant at different suction pressures. When all these compressors share a common condensing loop, it is impossible to address only the equipment serving refrigerated storage spaces. For compliance, the provisions addressing condensers, subsections 120.6(a)4A and 4B, apply only to new condensers that are part of new refrigeration systems when the total design capacity of all refrigerated storage spaces served by compressors using a common condensing loop is greater than or equal to 80 percent of the total design capacity.

In addition to an all-new refrigerated facility, the Energy Code covers expansions and modifications to an existing facility and an existing refrigeration plant. The Energy Code does not require that all existing equipment must comply when a refrigerated warehouse is expanded or modified using existing refrigeration equipment. Exceptions are stated in the individual equipment requirements and an explanation of applicability to additions and alterations is included in Section 10.4.

10.6.1.3 Ventilation

Section 120.1(a)1 of the Energy Code, concerning ventilation requirements, does not apply to "refrigerated warehouses and other spaces or buildings that are not normally used for human occupancy and work." The definition of refrigerated warehouses covers all refrigerated spaces greater than or equal to 3,000 ft,^{2} where mechanical refrigeration is at or below 55°F (13°C), which will in some instances include spaces with occupancy levels or durations, effect of stored product on space conditions, or other factors that may require ventilation for one or more reasons. Accordingly, while the Energy Code does not require ventilation for refrigerated warehouses, it is acknowledged that ventilation may be needed in some instances and is left to the determination of the owner and project engineer.

Example 10-28

Question:

A space that is part of a refrigerated facility is used solely to freeze meat products and not for storage. The design evaporator load is 310 Btu/hr-ft^2 at the applied conditions. Does the space have to comply with the space requirements in §120.1(a) of the Energy Codes?

Answer:

Yes. If the warehouse is 3,000 ft^2 or larger or served by a refrigeration system serving 3,000 ft^2 or more, it must meet all the requirements in subsections 1,2, 6, and 7. It also must meet the requirements of subsections 3A, 4C, 4D, 4E, 4F, 4G, 5A, and 5C. There are exceptions for 3B, 3C, 4A, 4B, and 5B.

Example 10-29

Question:

A refrigerated warehouse space is used to cool and store melons received from the field. After the product temperature is lowered, the product is stored in the same space for a few days until being shipped or sent to packaging. The design evaporator capacity is 300 Btu/hr-ft^2 at the applied conditions. Does the space have to comply with all the space requirements of §120.1(a) of the Energy Code?

Answer:

Yes. While the design evaporator capacity is greater than 240 Btu/hr-ft^2 and the space is used for product pull down for part of the time, the space is also used for holding product after it has been cooled. Accordingly, the space has to comply with the space requirements of §120.1(a) of the Energy Code.

Comment: This measure does not define a specific time limit that a quick chill (which for clarity includes quick "freeze") space could operate as a holding space (i.e., at full speed and thus full fan power). The typical high fan power density in a quick chill space, particularly at full speed after the high cooling load has been removed, is very inefficient. Thus, a reasonable expectation for a dedicated quick chill space is to allow no more time (at full speed) than is appropriate to remove the product in a normal business cycle of loading, cooling/freezing, and removing product once it has been reduced to temperature. If product is to be held any longer, variable speed is required to reduce fan power. Variable-speed requirements are discussed in under mechanical system requirements (sub-section 10.6.3B) of Chapter 10.

Example 10-30

Question:

A new refrigeration system serves both storage and quick chilling space. The design refrigeration capacity of the storage space is 500 tons. The design capacity of the quick chilling space is 50 tons. Is the refrigeration system required to meet all the requirements of §120.1(a) of the Energy Code?

Answer

Yes. Since more than 80 percent of the design capacity of the system serves storage space, the refrigeration system requirements apply.

Example 10-31

Question:

A new refrigerated warehouse is being constructed, which will include a 1,500 ft² cooler space and a 2,500 ft² freezer space. Both the cooler and freezer are served by a common refrigeration system. Is the refrigeration system required to comply with this standard?

Answer:

Since the suction group serves a total 4,000 ft² of refrigerated floor area, the spaces must meet all the requirements of §120.6(a).

10.6.2 Building Envelope Mandatory Requirements

Section 120.6(a) subsections 1, 2, and 6 of the Energy Code addresses the mandatory requirements for refrigerated space insulation, underslab heating, and infiltration barriers.

10.6.2.1 Envelope Insulation

§120.6(a)1

A. Wall and Roof Insulation

Manufacturers must certify that insulating materials comply with *California Quality Standards for Insulating Material* (C.C.R., Title 24, Part 12, Chapters 12-13), which ensure that insulation sold or installed in the state performs according to stated R-values and meets minimum quality, health, and safety standards. These standards state that all thermal performance tests shall be conducted on materials that have been conditioned at 73.4° ± 3.6°F and a relative humidity of 50 ± 5 percent for 24 hours immediately preceding the tests. The average testing temperature shall be 75° ± 2°F with at least a 40°F temperature difference. Builders may not install insulating materials unless the product has been certified by the Department of Consumer Affairs, Bureau of Home Furnishing and Thermal Insulation. Builders and enforcement agencies shall use the *Department of Consumer Affairs Directory of Certified Insulation Material* to verify certification of the insulating material.

Refrigerated spaces with 3,000 ft² of floor area or more shall meet the minimum R-Value requirements shown in Table 10-3.

Table 10-3: Refrigerated Warehouse Insulation

SPACE	SURFACE	MINIMUM R-VALUE (°F×hr×ft²/Btu)
Freezers	Roof/Ceiling	R-40
Freezers	Wall	R-36
Freezers	Floor	R-35
Freezers	Floor with all heating from productive refrigeration capacity	R-20
Coolers	Roof/Ceiling	R-28
Coolers	Wall	R-28

The R-values shown in Table 10-3 apply to all surfaces enclosing a refrigerated space, including refrigerated spaces adjoining conditioned spaces, other refrigerated spaces, unconditioned spaces, and the outdoors. If a partition is used between refrigerated spaces that are designed to always operate at the same temperature, the requirements do not apply. The R-values are the nominal insulation R-values and do not include other building materials or internal or external "film" resistances.

Example 10-32

Question

A refrigerated warehouse designed to store produce at 45°F (7°C) is constructed from tilt-up concrete walls and concrete roof sections. What is the minimum R-value of the wall and roof insulation?

Answer

Since the storage temperature is greater than 28°F (-2°C), the space is defined as a cooler. The minimum R-value of the wall and roof insulation according to Table 10-3 is R-28.

Example 10-33

Question

A refrigerated warehouse is constructed of a wall section consisting of 4 inches of concrete, 6 inches of medium density (2 lb/ft³) foam insulation, and another 4 inches of concrete. The nominal R-value of the foam insulation is R-5.8 per inch. What is the R-value of this wall section for code compliance?

Answer

The insulating value of the concrete walls is ignored. The R-value of this wall section for code compliance purposes is based on the 6 inches of foam insulation at R-5.8 per inch, or R-34.8.

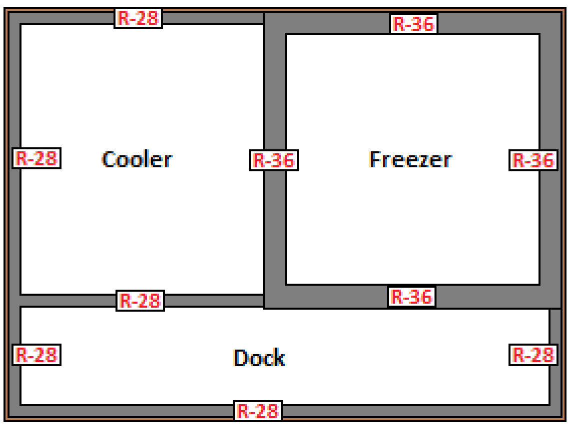
Example 10-34

Question

A 35°F cooler space is adjacent to a -10°F freezer space. What is the minimum required insulation R-value of the shared wall between the cooler and freezer spaces?

Answer

The minimum insulation R-value requirements should be interpreted to apply to all surfaces enclosing the refrigerated space at the subject temperature. Therefore, since the freezer space walls must be insulated to the minimum R-value requirements shown in Table 10-3, the R-value of the shared wall insulation must be at least R-36. The minimum insulation R-value requirement of the other three cooler walls is R-28. The figure below illustrates this example.



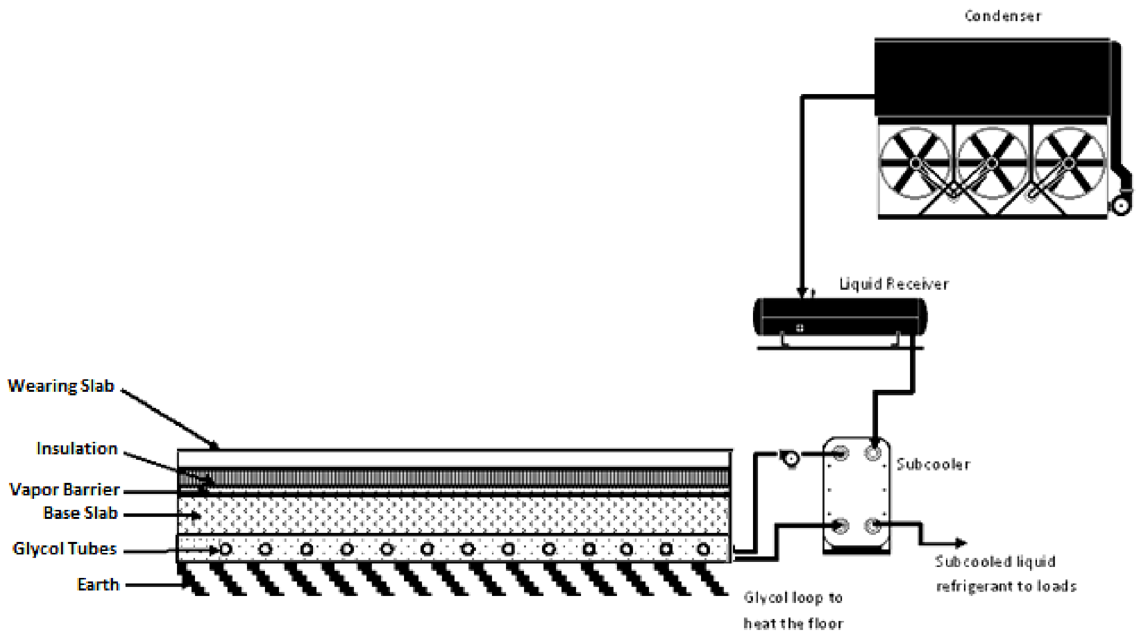
B. Freezer Floor Insulation

Freezer spaces with 3,000 ft² of floor area or more shall meet the minimum floor insulation R-value requirements shown in Table 10-3. The requirement is a minimum R-value of R-35, with an exception if the underslab heating system increases productive refrigeration capacity, in which case the minimum R-value is R-20.

The predominant insulating material used in freezer floors is extruded polystyrene, which is commonly available in 2"-thick increments but can be purchased in 1"-thick increments as well. Extruded polystyrene has an R-value of R-5 per inch at standardized rating conditions, and extruded polystyrene panels can be stacked, so the freezer floor can be constructed with R-value multiples of 5 (R-30, R-35, R-40).

A lower floor insulation R-value of R-20 is allowed if all the underslab heat is provided by an underslab heating system that increases productive refrigeration capacity. An example of an underslab heating system using heat from a refrigerant liquid subcooler is shown in Figure 10-27.

Figure 10-27: Underslab Heating System That Uses Refrigerant Subcooling



The lower R-value requirement when this type of underslab heating system is used is justified because the increased underslab heat gain to the space due to reduced insulation is offset by the heat extracted from the refrigerant liquid, which is a direct reduction in compressor load. The minimum requirement of R-20 does not mean that R-20 is the optimum or appropriate insulation choice in all installations. Rather, R-20 is a cost-effective trade-off when underfloor heating is obtained via productive refrigeration. Higher insulation levels combined with heating from productive refrigeration would improve efficiency.

10.6.2.2 **Underslab Heating Controls**

§120.6(a)2

Underslab heating systems should be used under freezer spaces to prevent soil freezing and expansion. The underslab heating element might be electric resistance, forced air, or heated fluid; however, underslab heating systems using electric resistance heating elements are not permitted unless they are thermostatically controlled and disabled during the summer on-peak period. The summer on-peak period is defined by the supplying electric utility but generally occurs from 12 p.m. to 6 p.m. weekdays from May through October. The control system used to control any electric resistance underslab heating elements must automatically turn the elements off during this on-peak period. The control system used to control electric resistance underslab heating elements must be shown on the building drawings, and the control sequence demonstrating compliance with this requirement must be documented on the drawings and in the control system specifications.

10.6.2.3 Infiltration Barriers

120.6(a)6

Passageways between freezers and higher-temperature spaces, and passageways between coolers and nonrefrigerated spaces, shall have an infiltration barrier such as:

h. Strip curtains.

i. An automatically closing door.

j. Air curtain.

Examples of each are shown in the figures below.

Figure 10-28: Strip Curtains

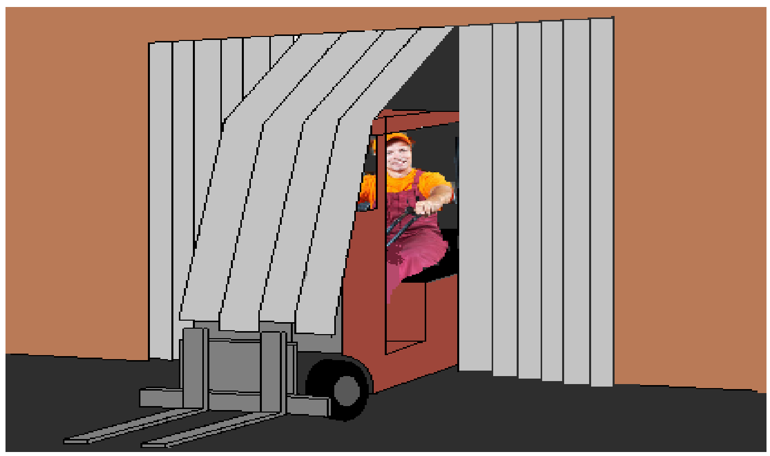


Figure 10-29: Biparting Automatic Door

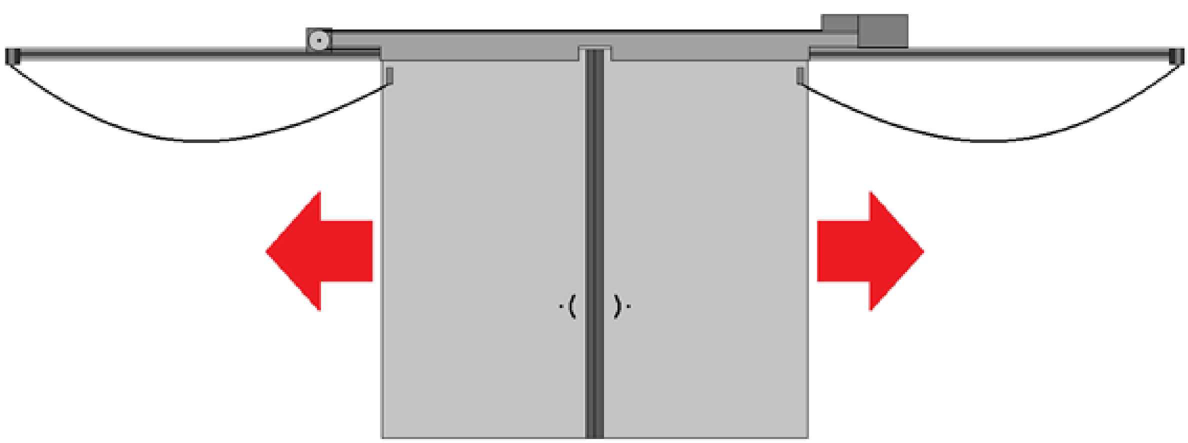


Figure 10--30: Hinged Door with Spring-Action Door Closer and Door "Tight" Closer

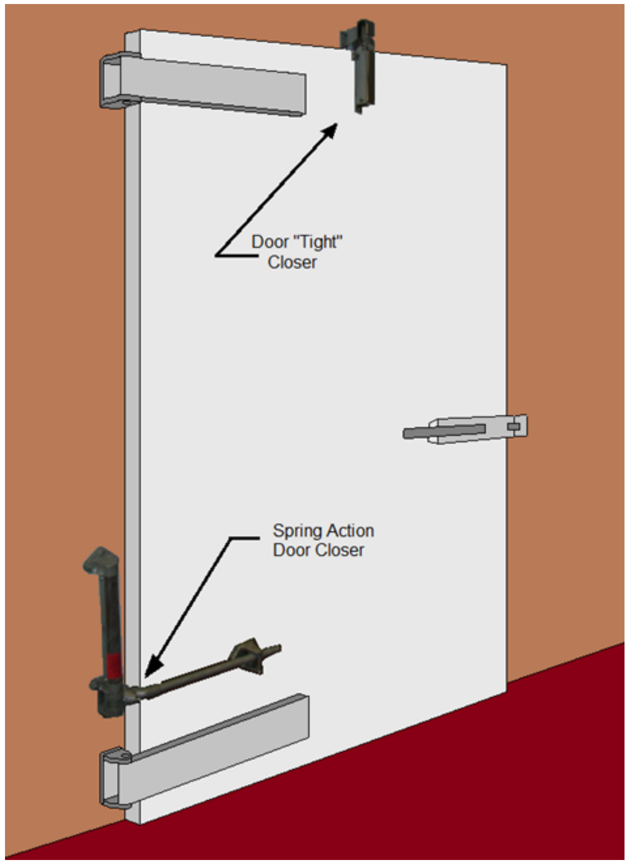
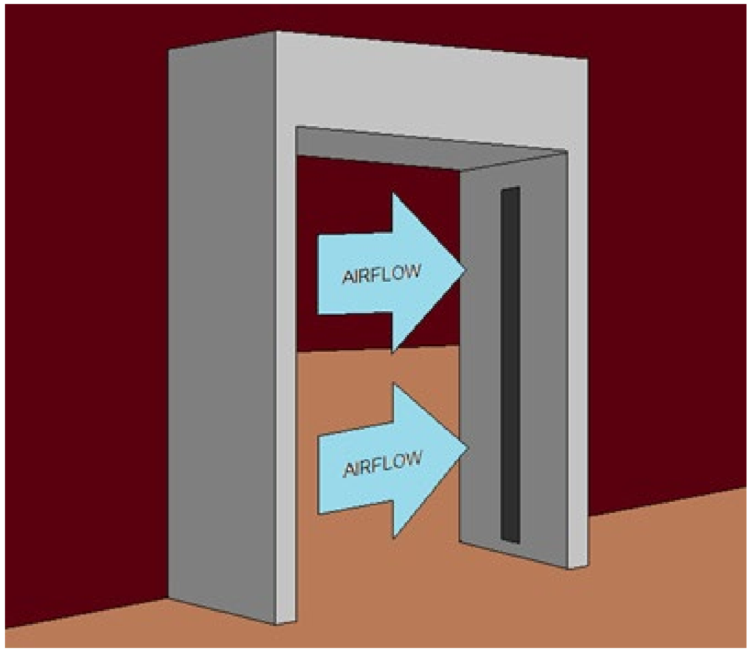


Figure 10-31: Air Curtain



The passageways may be for, but are not limited to, people, forklifts, pallet lifts, hand trucks, or conveyor belts.

Strip curtains are commercial flexible plastic strips made for refrigerated openings with material type, weight, and overlap designed for the size of the passageway opening and the temperatures of the subject spaces.

An automatically closing door is a door that fully closes under its own power. Examples include:

a. Single-acting or double-acting hinge-mounted doors with a spring assembly or cam-type gravity hinges.

b. Powered single sliding, biparting, or rollup doors that open based on a pull cord, proximity or similar sensors, or by operator signal and close automatically through similar actions or after a period sufficient to allow passageway transit.

An air curtain is a commercial fan-powered assembly intended to reduce air infiltration and designed by the manufacturer for use on refrigerated warehouse passageways and on the opening size and the temperatures for which it is applied.

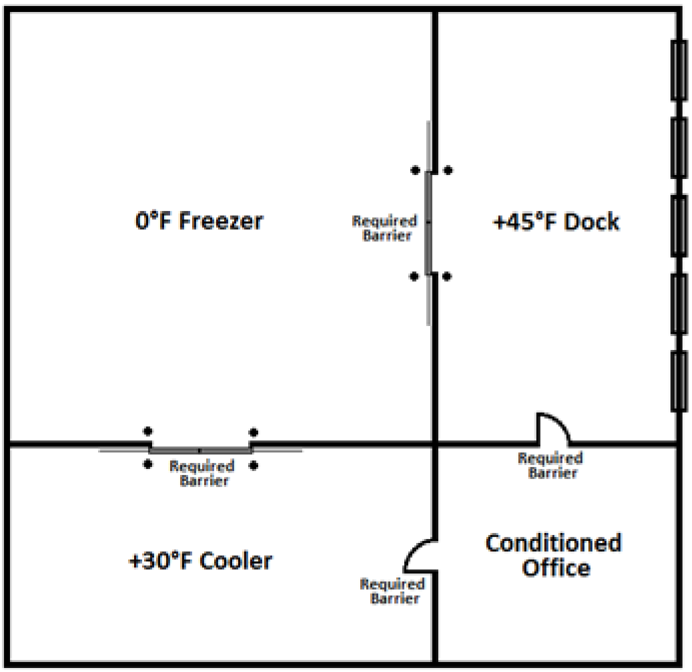
There are two exceptions to the requirements for infiltration barriers:

1. Openings with less than 16 ft^2 of opening area, such as small passageways for conveyor belts
2. Loading dock doorways for trailers.

Example 10-35

Question

A refrigerated warehouse includes a freezer, cooler, a refrigerated dock, and a conditioned office, as shown in the following figure. Where are infiltration barriers required?



Answer

Infiltration barriers are required between all spaces, including the hinge-mounted doors between the dock and the office. The dock doors do not require infiltration barriers.

Example 10-36

Question

A refrigerated warehouse is being constructed for a flower distribution company. Strip curtains cannot be used on the doors because the strips will damage the flowers when the pallet jack passes through. Is the warehouse still required to have infiltration barriers?

Answer

Yes, the warehouse is required to have infiltration barriers. If strip curtains cannot be used, the designer may choose another method, such as double-acting hinged doors, sliding doors, or rollup doors with automatic door closers.

10.6.2.4 Automatic Door Closers

§120.6(a)9

Infiltration through doors in refrigerated warehouses account for significant amounts of wasted energy.

The Energy Code requires that doors designed for the passage of people that are between freezers and higher-temperature spaces, or coolers and nonrefrigerated spaces, have automatic door closers.

Automatic door closers are typically hinges that closes a door from any open position and mechanisms that closes a door completely shut, if slightly ajar (from approximately 1 inch opened).

10.6.2.5 Acceptance Requirements

§120.6(a)7

The Energy Code includes acceptance test requirements for electric resistance underslab heating systems in accordance with NA7.10.1. The test requirements are described in Chapter 13 and the Reference Nonresidential Appendix NA7.10. The test requirements are described briefly in the following paragraph.

A. Electric Resistance Underslab Heating System

NA7.10.1

The acceptance requirements include functional tests that are to be performed to verify that the electric resistance underslab heating system automatically turns off during a test on-peak period.

10.6.3 Mechanical Systems Mandatory Requirements

10.6.3.1 Overview

This section addresses mandatory requirements for mechanical systems serving refrigerated spaces. Mechanical system components addressed by the Energy Code includes evaporators (air units), compressors, condensers, and refrigeration system controls. The requirements for each of these components are described in the following sections. The requirements apply to all system and component types with the exception of the specific exclusions noted in §120.6(a). The following figures identify some of the common system and component configurations that fall under §120.6(a).

Figure 10-32 is a schematic of a single-stage system with direct expansion (DX) evaporator coils. Figure 10-33 identifies a single-stage system with flooded evaporator coils, while Figure 10-34 shows a single-stage system with pump recirculated evaporators. Figure 10-35 is a schematic of a typical two-stage system with an intercooler between the compressor stages. Figure 10-36 is a single-stage system with a water-cooled condenser and fluid cooler.

Figure 10-32: Single-Stage System with DX Evaporator Coil

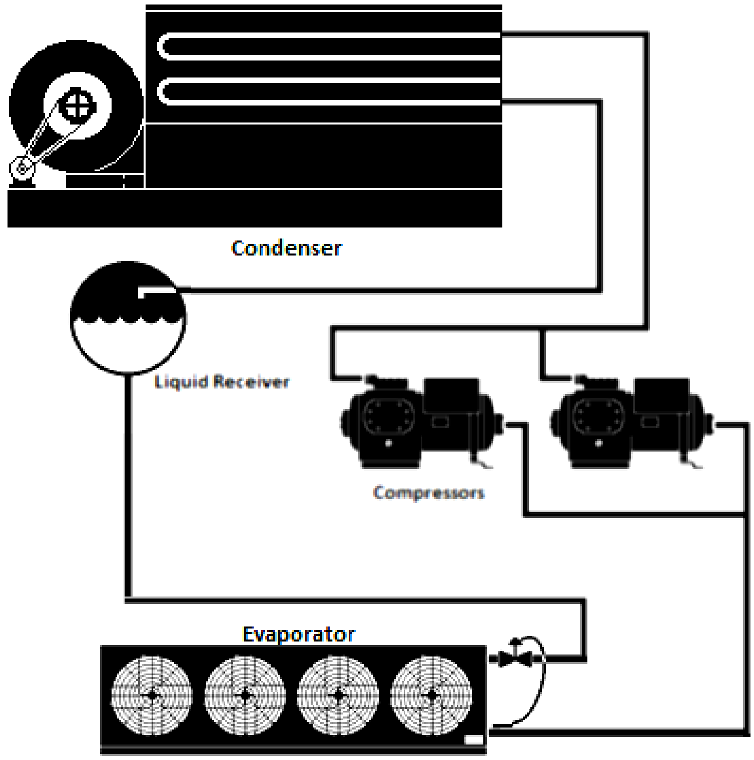


Figure 10--33: Single-Stage System with Flooded Evaporator Coil

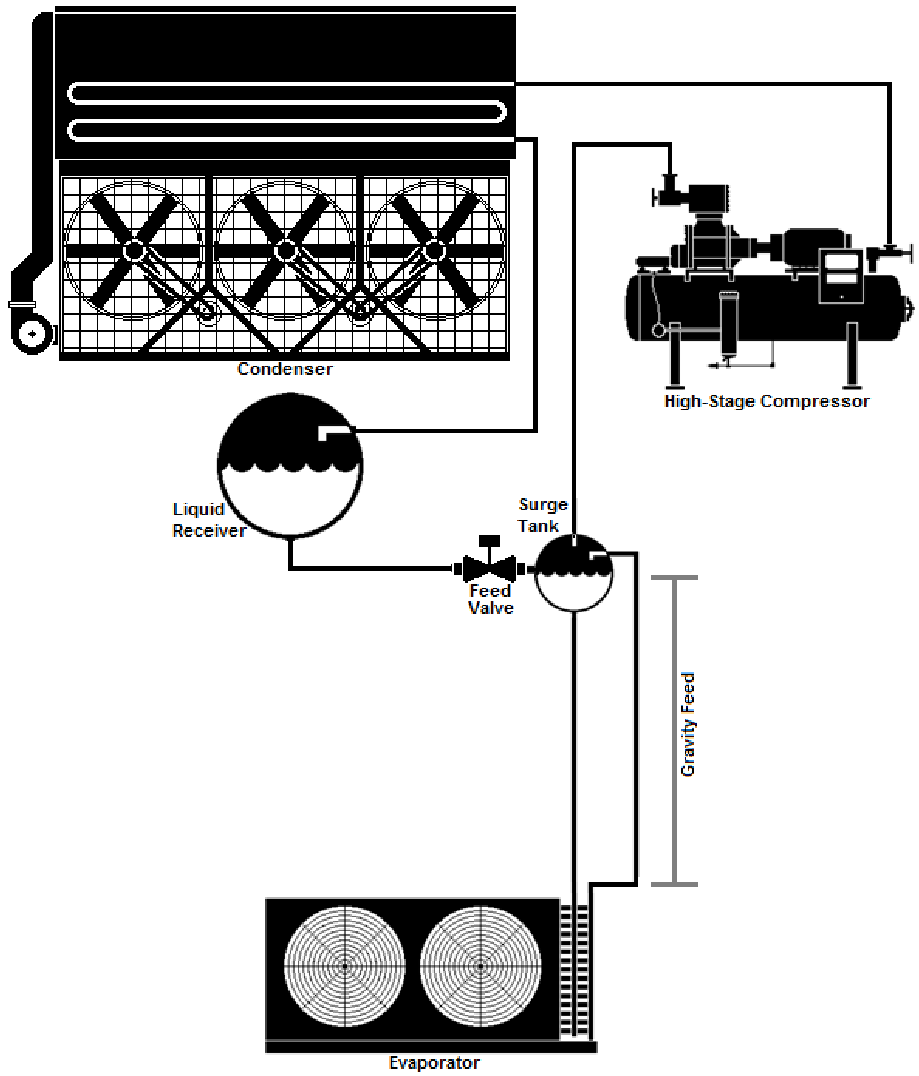


Figure 10-34: Single-Stage System with Pump Recirculated Evaporator Coils

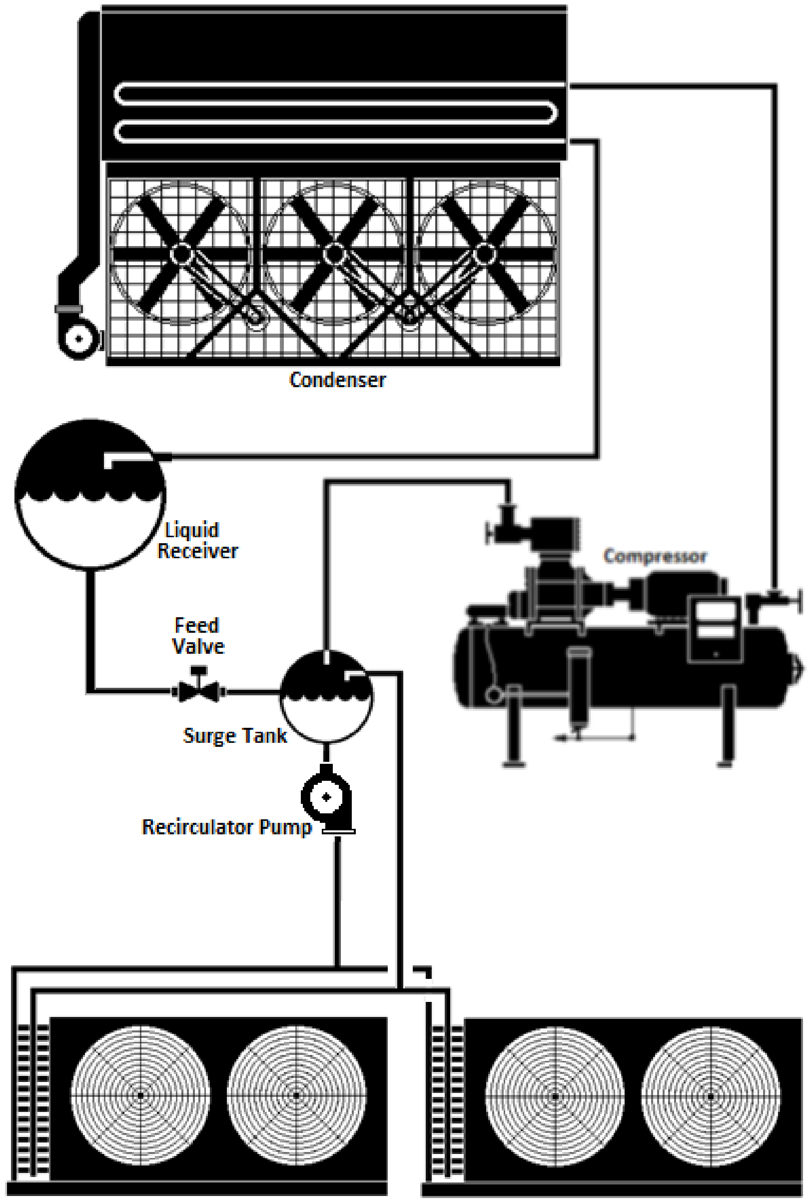


Figure 10-35: Two-Stage System with Flooded Evaporator Coil

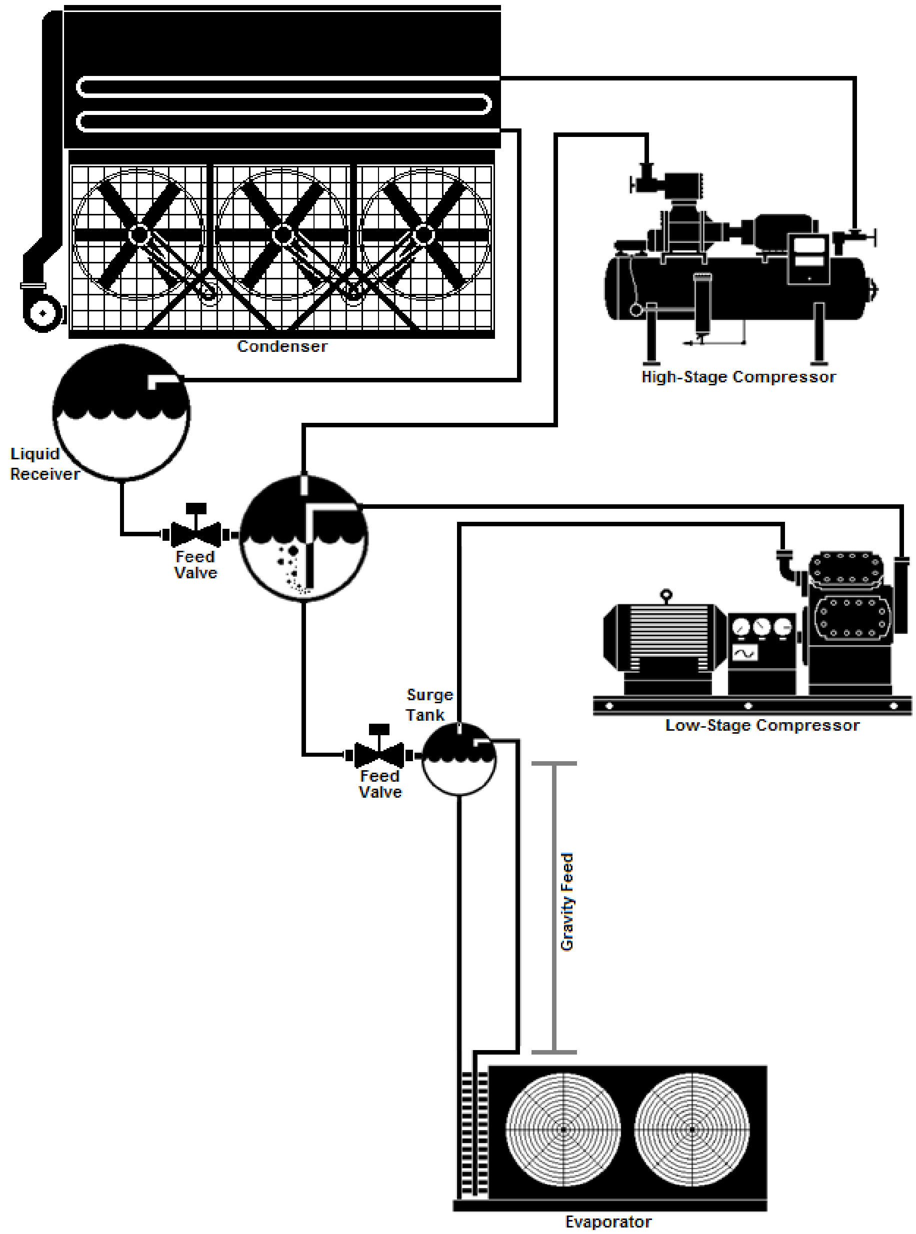
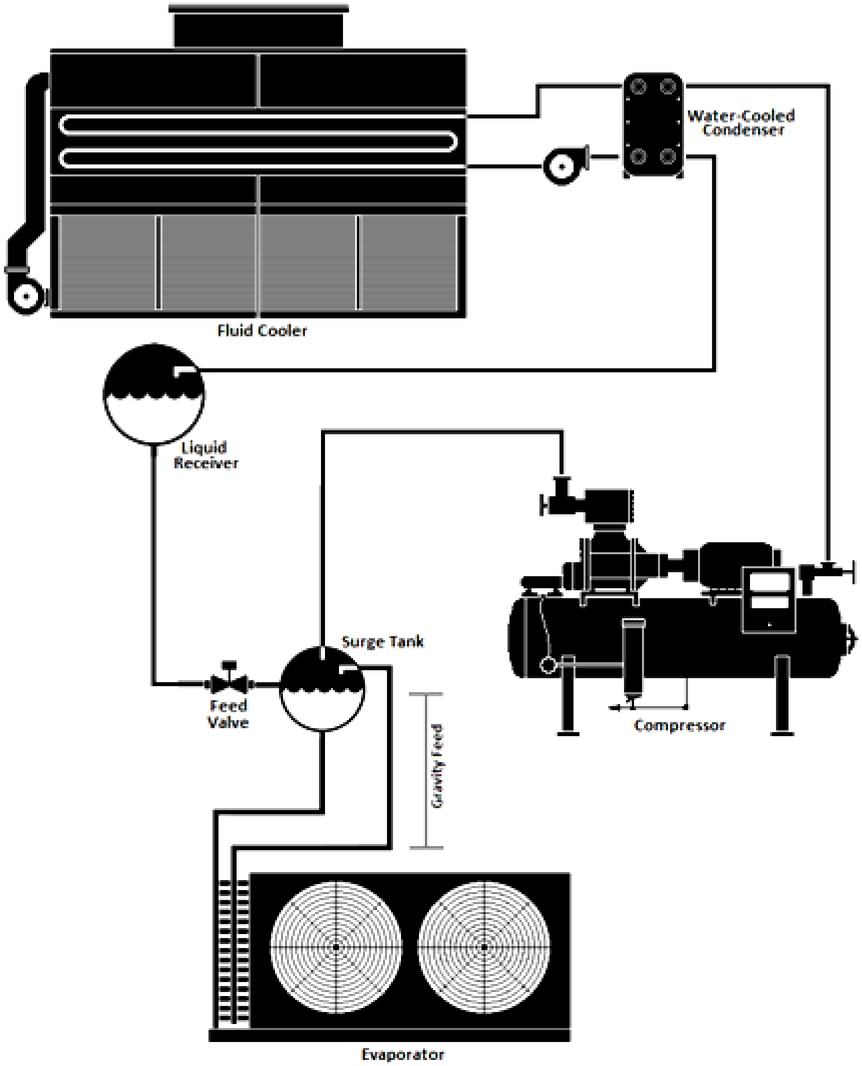


Figure 10-36: Single-Stage System with Water-Cooled Condenser Served by Fluid Cooler



10.6.3.2 **Evaporators**

§120.6(a)3

New fan-powered evaporators used in coolers and freezers must meet the fan motor type, efficiency, and fan control requirements outlined in the Energy Code.

A. Allowed Fan Motor Types

Single-phase fan motors less than 1 horsepower and less than 460 volts must be either electronically commutated (EC), also known as Brushless Direct Current (DC), or must have an efficiency of 70 percent or more when rated in accordance with NEMA Standard MG 1-2006 at full-load rating conditions. This requirement is designed to reduce fan power in small evaporator fans.

B. Fan Motor Control

The speed of all evaporator fans served by either a suction group with multiple compressors or by a single compressor with variable-capacity capability must be controlled in response to space temperature or humidity using a continuously variable-speed control method. Two-speed control of evaporator fans is not an acceptable control method.

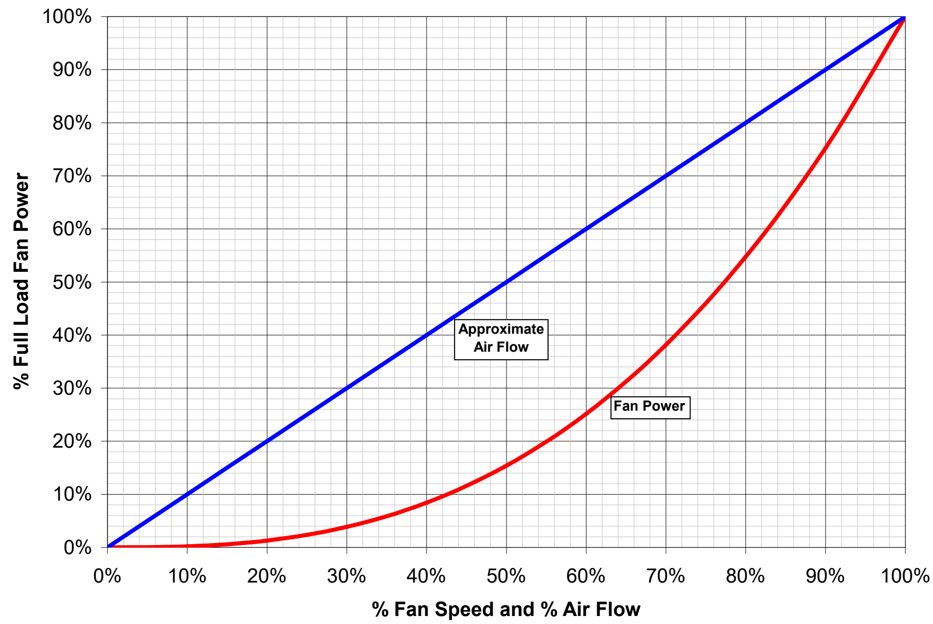
The fan speed is controlled in response to space temperature or humidity. Fan speed should increase proportionally when the space temperature is above the set point and decrease when the space temperature is at or below the set point, with refrigerant supply and pressure being maintained in the evaporator cooling coil. Fan speed is equivalent to air volume being circulated, resulting in direct control of cooling capacity, analogous to "variable air volume" cooling in commercial buildings. The control logic requires design and tuning to provide "variable" capacity operation.

The use of humidity as the control variable for speed control is very limited in practice but is included in the Energy Code to accommodate special strategies for humidity-sensitive perishable product. Control logic in these applications will often employ humidity in conjunction with temperature.

The intent of this requirement is to take advantage of the "third-power" fan affinity law, which states that the percentage of required fan motor power is roughly equal to the cube of the percentage of fan speed, while the airflow is linearly proportional to the fan speed. For example, a fan running at 80 percent speed requires about 51 percent ($80\%^3 = 51\%$) power while providing nearly 80 percent airflow (Figure 10-37). Actual power is somewhat higher due to inefficiencies and drive losses. This shows the relationship between fan speed and both required fan power and approximate airflow.

There is no requirement in the Energy Code for the minimum speed setting (i.e., how low the fan speed must go at minimum load). Variable-speed controls of evaporator fans have commonly used minimum speeds of 80 percent or lower on direct expansion coils and 70 percent or lower on flooded or recirculated coils. The allowable minimum fan speed setting is to be determined by the refrigeration system designer. The fan speed may be adjusted or controlled to maintain adequate air circulation to ensure product integrity and quality.

Figure 10-37: Relationship Between Fan Speed and Required Power



Correct fan speed control requires the associated system suction pressure to be controlled such that evaporator capacity is sufficient to meet space loads. If the evaporator suction pressure is too high relative to the desired room temperature, the evaporator fans will run at excessively high speed, and energy savings will not be realized. If floating suction pressure automation is used to optimize the suction pressure set point, suction pressure should be allowed only to float up after fan speeds are at minimum and should be controlled to float back down prior to increasing fan speeds.

The Energy Code has three exceptions to the evaporator variable speed requirement:

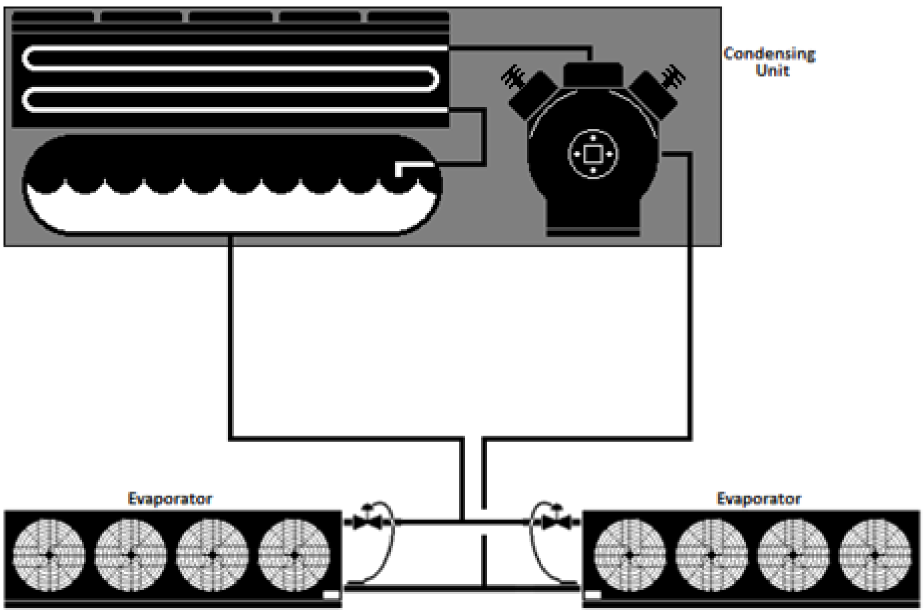
1. In case of a replacement, addition, or alteration of existing evaporators with no variable-speed control, the variable-speed control of the evaporators is mandatory only if the replacement, addition, or alteration is done for all the evaporators in an existing space. *[Exception 1 to §120.6(a)3B]*
2. A controlled atmosphere (CA) storage where products that require 100 percent of the design airflow at all times are stored may be exempt from the variable-speed control requirement. A licensed engineer must certify that the products in the cooler require continuous airflow at 100 percent speed. Variable-speed control must be implemented if the space will also be used for non-CA product or operation. *[Exception 2 to §120.6(a)3B]*
3. The variable-speed control is not mandatory for spaces that are used solely for quick chilling or quick freezing of products. Such spaces have design cooling

capacities that are greater than 240 Btu/hr-ft² of floor area, which is equivalent to 2 tons per 100ft² of floor area. However, variable-speed control must be implemented if the spaces are used for storage for any length of time, regardless of how much refrigeration capacity is installed in the space. [Exception 3 to §120.6(a)3B].

Example 10-37

Question:

A split system with a packaged air-cooled condensing unit with a single 30 HP compressor with unloaders serves two direct expansion evaporators in a 3,200 ft² cooler. Are the evaporator fans required to have variable-speed control?



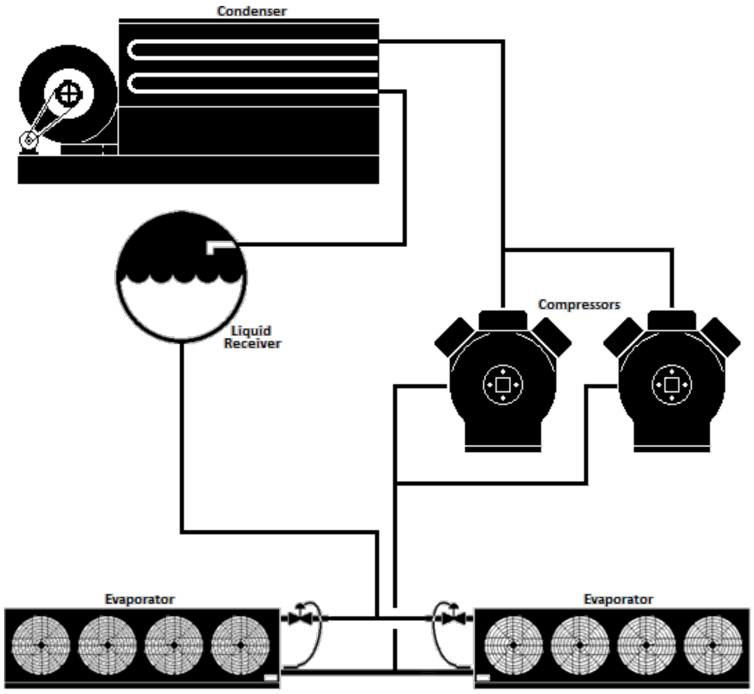
Answer:

Yes. Since the compressor has a variable-capacity capability in the form of unloaders, the evaporator fans are required to have variable-speed control.

Example 10-38

Question:

A refrigeration system uses two reciprocating compressors without variable-capacity capability connected in parallel and serves multiple evaporators in a 10,000 ft² cooler. Are the evaporator fans required to have variable-speed control?



Answer:

Yes. Since the evaporators are served by more than one compressor, they must have variable-speed control, even though the compressors are not equipped with capacity control devices (e.g., unloaders).

In practice, the designer should consider the steps of capacity necessary to allow stable control. For small systems, the designer may consider use of proportional controls for compressor capacity steps and speed steps in unison. As long as this control scheme is in response to space temperature, it would be consistent with the Energy Code.

Example 10-39

Question:

A -20°F (-29°C) freezer has several recirculated evaporator coils that were selected to meet the design load at a 10°F (5.5°C) temperature difference (TD). The evaporator fan motors use variable-speed drives, and the control system varies the fan speed in response to space temperature. What should the freezer saturated suction temperature be to achieve proper control and savings – by allowing fan speed control to act as the primary means of temperature control.

Answer:

Since the coils were designed at a 10°F (5.5°C) TD and the target freezer temperature is -20°F (-29°C), the saturated evaporating temperature should be -30°F (-34°C) (-20°F minus 10°F), with the compressor controlled at a lower temperature, based on the design piping pressure drop. For example, with 2°F (1°C) of piping losses, the compressor control set point would be -32°F (-36°C).

This example sought to show how evaporator temperature and coil capacity can be considered and maintained to achieve proper variable-speed fan operation and savings. Settings could be fine-tuned through observation of the required suction pressure to meet cooling loads and achieve minimum fan speeds average load periods, yet with a suction pressure no lower than necessary.

Example 10-40

Question:

An existing refrigerated warehouse space has eight evaporators that do not have variable-speed control. Six of the eight evaporators are being replaced with new evaporators. Do the new evaporators require variable-speed control?

Answer:

No. Since all the evaporators are not being replaced, the new evaporators do not require variable-speed control.

The reason for this is that effective space temperature control would often require that the entire space use a consistent control scheme that could require a disproportional cost. While not required by the Energy Code, in many instances it may still be very cost-effective to add variable-speed control to existing as well as new evaporators in this situation.

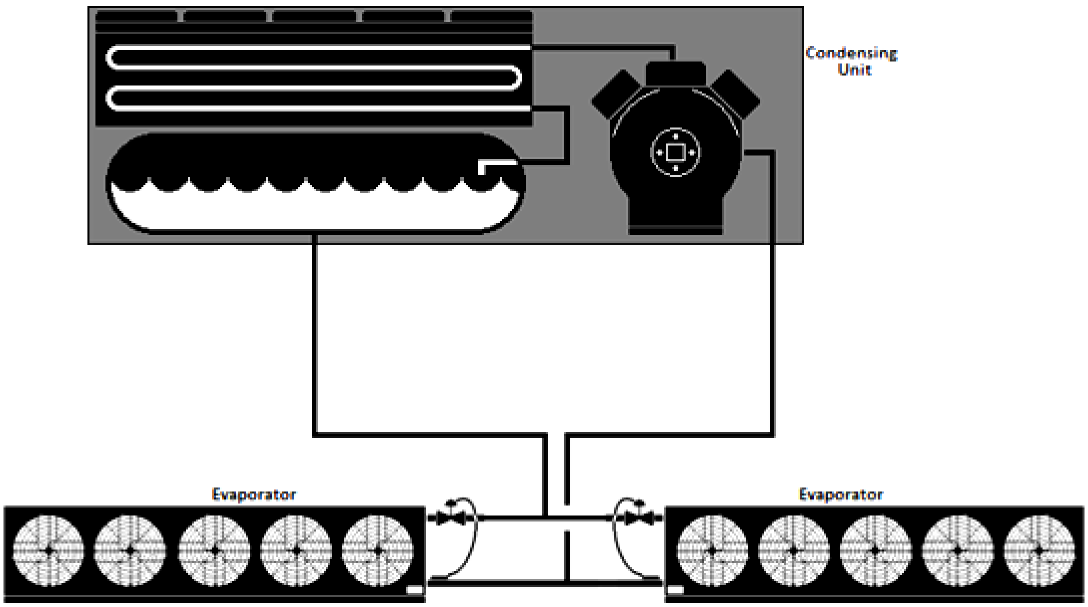
Continuously variable-speed control is not mandatory for evaporators that are served by a single compressor that does not have variable-capacity capability (i.e., the compressor cycles on and off in response to space temperature). For these systems, evaporator airflow must be reduced by at least 40 percent when the compressor is off. This can be accomplished in several ways, for example:

- Two-speed evaporator fan control, with speed reduced by at least 40 percent when cooling is satisfied and the compressor is off.
- Turning off a portion of the fans in each evaporator to accomplish at least 40 percent reduction in fan power. Typically, baffles are required to prevent reverse flow through fans that are turned off.
- Turning off all fans when the compressor is off. With this strategy a duty cycle can be employed to provide period forced fan operation to maintain air circulation, if the “on” period is limited to 25 percent of the duty cycle while the compressor is off.

Example 10-41

Question:

A split system with a packaged air-cooled condensing unit using a single cycling compressor without unloaders serves two evaporators in a cooler. Each evaporator has five fans. What options does the system designer have to meet the requirements for evaporator coils served by a single cycling compressor?



Answer:

Multiple methods can be used to reduce airflow by at least 40% when the compressor is off or turn all fans off with a 25% duty cycle.

Example 1: The designer may specify two-speed fans or utilize variable-frequency drives or other speed-reduction devices to reduce the fan speed to 60% or less when the compressor is off.

Example 2: The designer may use controls that cycle at least 4 of the 10 fans off when the compressor is cycled off. This would most likely be accomplished by cycling two fans off on each evaporator.

10.6.3.3 **Condensers**

§120.6(a)4

New condensers on new refrigeration systems must follow the condenser sizing, fan control, and efficiency requirements as described in §120.6(a)4.

A. Condenser Sizing

§120.6(a)4A and §120.6(a)4B describe minimum sizing requirements for new condensers serving new refrigeration systems. Fan-powered evaporative condensers, as well as water-cooled condensers served by fluid coolers and cooling towers, are covered in §120.6(a)4A. Fan-powered air-cooled condensers are covered by §120.6(a)4B. Fan-powered adiabatic condensers are covered by §120.6(a)4C.

Condensers must be sized to provide sufficient heat rejection capacity under design conditions while maintaining a specified maximum temperature difference between the refrigeration system saturated condensing temperature (SCT) and ambient temperature. The design condenser capacity shall be greater than the calculated combined total heat of rejection (THR) of the dedicated compressors that are served by the condenser. If multiple condensers are specified, then the combined capacity of the installed condensers shall be greater than the calculated heat of rejection. When determining the design THR for this requirement, reserve or backup compressors may be excluded from the calculations.

There is no limitation on the type of condenser that may be used. The choice may be made by the system designer, considering the specific application, climate, water availability, etc.

The Energy Code includes an exception to §120.6(a)4A, 4B, and 4C for condensers serving refrigeration systems for which more than 20 percent of the design cooling load comes from quick chilling or freezing space, or process (nonspace) refrigeration cooling. The Energy Code defines quick chilling or freezing space as a space with a design refrigeration evaporator capacity greater than 240 Btu/hr-ft² of floor area, which is equivalent to 2 tons per 100 ft² of floor area, at system design conditions.

Another exception to §120.6(a)4B, for air-cooled condenser sizing, applies if a condensing unit has a total compressor power less than 100 hp. A condensing unit includes compressor(s), condenser, liquid receiver, and control electronics that are packaged in a single product.

Example 10-42

Question:

A new food processing plant is being constructed that will include an 800 ft² blast freezer, a holding freezer, and a loading dock. The design evaporator capacity of the blast freezer is 40 tons of refrigeration (TR). The combined evaporator capacity of the freezer and loading dock is 60 TR. Does the condenser group have to comply with the sizing requirements in §120.6(a)4A?

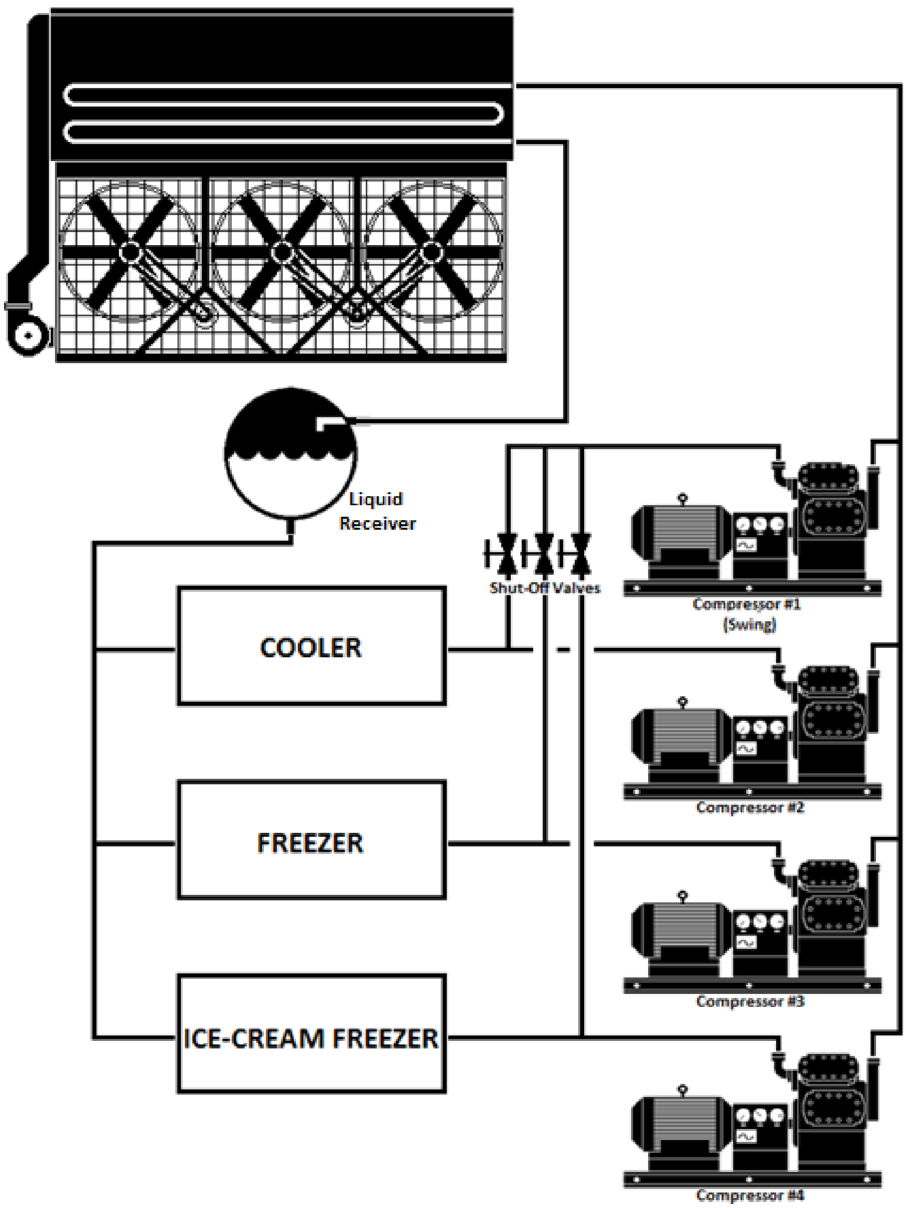
Answer:

The blast freezer evaporator capacity divided by the floor area is 40 TR/800 ft², which is equal to 5 TR/100 ft². That means this particular blast freezer is deemed quick freezing space by the Energy Code. Therefore, the condenser group serving the refrigeration system does not have to comply with §120.6(a)4A, because 40% (i.e., greater than 20%) of the design refrigeration capacity is from quick freezing.

Example 10-43

Question:

The refrigerated warehouse system shown below has a backup or "swing" compressor. Does the heat rejection from this compressor need to be included in the condenser sizing calculations?



Answer:

It depends.

A swing compressor may be designed solely for backup of multiple suction groups, or it may be included in one suction group and necessary to meet the design load of that suction group, but in an emergency is also capable of providing backup for other compressors. If the compressor is solely for use as backup, it would be excluded from the heat rejection calculation for the purposes of the Energy Code. In this case, the calculations would include the heat of rejection from Compressors 2, 3, and 4 and would exclude Compressor 1.

1. Sizing of Evaporative Condensers, Fluid Coolers, and Cooling Towers

§120.6(a)4A

§120.6(a)4A provides maximum design SCT values for evaporative condensers as well as systems consisting of a water-cooled condenser served by a cooling tower or fluid cooler. For this section, designers should use the 0.5 percent design wet bulb temperature (WBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement. The maximum design SCT requirements are listed in Table 10-4 below.

Table 10-4: Maximum Design SCT Requirements for Evaporative Condensers and Water-Cooled Condensers Served by Cooling Towers and Fluid Coolers

0.5% DESIGN WET BULB TEMPERATURE	MAXIMUM DESIGN SCT
£ 76°F (24°C)	Design WBT plus 20°F (11°C)
Between 76°F (24°C) and 78°F (26°C)	Design WBT plus 19°F (10.5°C)
³ 78°F (26°C)	Design WBT plus 18°F (10°C)

Example 10-44

Question:

A refrigerated warehouse is being constructed in Fresno. The refrigeration system will be served by an evaporative condenser. What is the sizing requirement for the condenser selected for this system?

Answer:

The 0.5% design wet bulb temperature (WBT) from Joint Appendix JA-2 for Fresno is 73°F. Therefore, the maximum design SCT for the refrigerant condenser is 73°F + 20°F = 93°F. The selected condenser for this system must be capable of rejecting the total system design THR at 93°F SCT and 73°F WBT.

Example 10-45

Question:

What is the minimum size for a condenser for a refrigeration system with the following parameters?

Located in Fresno

Design SST: 10°F

Suction group: Three equal-sized dedicated 100 hp screw compressors (none are backup units)

Evaporative condenser

240 TR cooling load

Answer:

From the previous example, it was determined that the design wet bulb temperature (WBT) to demonstrate compliance for Fresno is 73°F, and the maximum design SCT for the evaporative condenser is 93°F (73°F + 20°F). We will assume the system designer determined a 2°F loss between the compressors and condenser. The designer first calculates the THR for the suction group at the design conditions of 10°F SST and 95°F SCT. Each selected compressor has a rated capacity of 240 TR and will absorb 300 horsepower at the design conditions. Therefore, the calculated THR for one compressor is:

240 TR / compressor x 3 compressor x 12,000 Btuh/TR + 300HP x 2,545 Btuh/HP = 9,403,500 Btuh

To comply with the Energy Code, a condenser (or group of condensers) must be selected that is capable of rejecting at least 9,403,500 Btu/hr at 93°F SCT and 73°F WBT.

2. Sizing of Air-Cooled Condensers

§120.6(a)4B

§120.6(a)4B provides maximum design SCT values for air-cooled condensers. For this section, designers should use the 0.5 percent design dry bulb temperature (DBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement.

Standard practice is for published condenser ratings to assume the capacity of air-cooled condensers is proportional to the temperature difference (TD) between SCT and DBT, regardless of the actual ambient temperature entering the condenser. For example, the capacity of an air-cooled condenser operating at an SCT of 80°F with a DBT of 70°F is assumed to be equal to the same unit operating at 110°F SCT and 100°F DBT, since the TD across the condenser is 10°F in both examples. Thus, unlike evaporative condensers, the requirement for air-cooled condensers does not have varying sizing requirements for different design ambient temperatures.

However, the Energy Code has different requirements for air-cooled condensers depending on the space temperatures served by the refrigeration system. The maximum design SCT requirements are listed in Table 10-5 below:

Table 10-5: Maximum Design SCT Requirements for Air-Cooled Condensers

REFRIGERATED SPACE TYPE	SPACE TEMPERATURE	MAXIMUM SCT
Cooler	≥ 28°F (-2°C)	Design DBT plus 15°F (8.3°C)
Freezer	< 28°F (-2°C)	Design DBT plus 10°F (5.6°C)

Often, a single refrigeration system and the associated condenser will serve a mix of cooler and freezer spaces. In this instance, the maximum design SCT shall be a weighted average of the requirements for cooler and freezer spaces, based on the design evaporator capacity of the spaces served.

Example 10-46

Question:

An air-cooled condenser is being sized for a system that has half of the associated installed capacity serving cooler space and the other half serving freezer space. What is the design TD to be added to the design dry bulb temperature?

Answer:

This measure specifies a design approach of 15°F (8.3°C) for coolers and 10°F (5.6°C) for freezers. When a system serves freezer and cooler spaces, a weighted average should be used based on the installed capacity. To calculate the weighted average, multiply the percentage of the total installed capacity dedicated to coolers by 15°F (8.3°C). Next, multiply the percentage of the total installed capacity dedicated to freezers by 10°F (5.6°C). The sum of the two results is the design condensing temperature approach. In this example, the installed capacity is evenly split between freezer and cooler space. As a result, the design approach for the air-cooled condenser is 12.5°F (6.9°C).

(50% x 15°F*) + (50% x 10*°F*) = 7.5*°F *+ 5*°F *= 12.5*°F

3. **Adiabatic Condenser Sizing**

§120.6(a)4C

§120.6(a)4C provides maximum design SCT values for adiabatic condensers. These requirements are the same as for §120.6(b)1E. See section 10.5.2.3 for details.

B. Fan Control

Condenser fans for new air-cooled, evaporative, or adiabatic condensers, or fans on cooling towers or fluid coolers used to reject heat on new refrigeration systems, must use continuously variable-speed. Variable-frequency drives are commonly used to provide continuously variable-speed control of condenser fans, although controllers designed to vary the speed of electronically commutated motors may be used to control these types of motors. All fans serving a common high side, or cooling water loop for cooling towers and fluid coolers, shall be controlled in unison. Thus, in normal operation, the fan speed of all fans within a single condenser or set of condensers serving a common high side should modulate together, rather than running fans at different speeds or staging fans off. However, when fan speed is at the minimum practical level usually no higher than 10-20%, the fans may be staged off to reduce condenser capacity. As load increases, fans should be turned back on before significantly increasing fan speed, recognizing a control band is necessary to avoid excessive fan cycling.

To minimize overall system energy consumption, the condensing temperature set point must be continuously reset in response to ambient temperatures, rather than using a fixed set point value. This strategy is also termed ambient-following control, ambient-reset, wet bulb following and dry bulb following—all referring to the control logic that changes the condensing temperature target in response to ambient conditions at the condenser. The control system calculates a target saturated condensing temperature that is higher than the ambient temperature by a predetermined temperature difference (i.e., the condenser control TD). Fan speed is then modulated according to the calculated target SCT. The target SCT for evaporative condensers or water-cooled condensers (via cooling towers or fluid coolers) must be reset according to ambient wet bulb temperature, the target SCT for air-cooled condensers must be reset according to ambient dry bulb temperature, and the target SCT for adiabatic condensers when operating in dry mode must be reset according to ambient dry bulb temperature. There is no requirement for SCT control during wet bulb (adiabatic) operation. This requirement for the adiabatic condenser is applicable to all systems and is independent of the type of refrigerant used

The condenser control TD is not specified in the Energy Code. The nominal control value is often less than the condenser design TD; however, the value for a particular system is left up to the system designer. Since the intent is to use as much condenser capacity as possible without excessive fan power, a common practice for refrigerated warehouse systems is to optimize the control TD over a period such that the fan speed is between approximately 60 and 80% during normal operation (i.e., when not at minimum SCT). While not required, evaporative condensers and systems using fluid coolers and cooling towers may also vary the condenser control TD as a function of actual WBT to account for the properties of moist air, which reduce the effective condenser capacity at lower wet bulb temperatures.

The minimum saturated condensing temperature set point must be 70°F (21°C) or less. For systems using halocarbon refrigerants with glide, the SCT set point shall correlate with a midpoint temperature (between the refrigerant bubble-point and dew-point temperatures) of 70°F (21°C) or less. As a practical matter, a maximum SCT set point is also commonly employed to set an upper bound on the control set point in the event of a sensor failure and to force full condenser operation during peak ambient conditions. This value should be set high enough that it does not interfere with normal operation.

Split air-cooled condensers are sometimes used for separate refrigeration systems, with two circuits and two rows of condenser fans. Each condenser half would be controlled as a separate condenser. If a condenser has multiple circuits served by a common fan or set of fans, the control strategy may use the average condensing temperature or the highest condensing temperature of the individual circuits as the control variable for controlling fan speed.

Alternative control strategies are permitted to the condensing temperature reset control required in §120.6(a)4E. The alternative control strategy must be demonstrated to provide equal or better performance, as approved by the Executive Director.

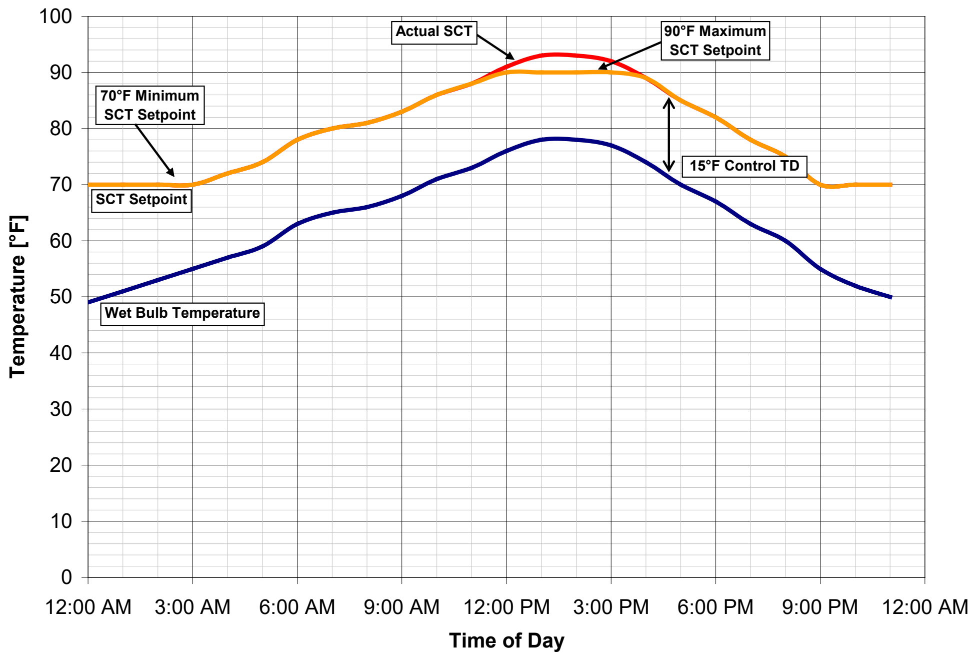
Example 10-47

Question

A refrigerated warehouse with evaporative condensers is being commissioned. The control system designer has used a wet bulb-following control strategy to reset the system saturated condensing temperature (SCT) set point. The refrigeration engineer has calculated that adding a TD of 15°F (8.3°C) above the ambient wet bulb temperature should provide a saturated condensing temperature set point that minimizes the combined compressor and condenser fan power usage throughout the year. What might the system SCT and SCT set point trends look like over an example day?

Answer

The following figure illustrates what the actual saturated condensing temperature and SCT set points could be over an example day using the wet bulb-following control strategy with a 15°F (8.3°C) TD and observing the 70°F (21°C) minimum condensing temperature requirement. As the figure shows, the SCT set point is continuously reset to 15°F (8.3°C) above the ambient wet bulb temperature until the minimum SCT set point of 70°F is reached. The figure also shows a maximum SCT set point (in this example, 90°F (32.2°C) that may be used to limit the maximum control set point, regardless of the ambient temperature value or TD parameter.



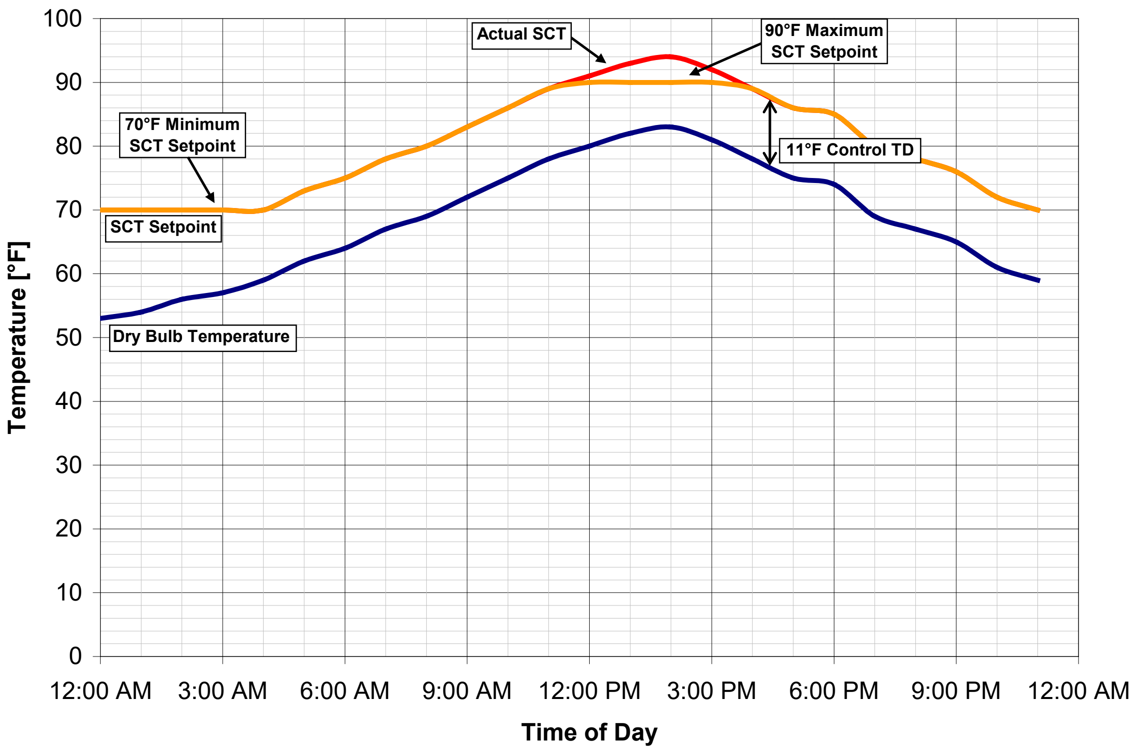
Example 10-48

Question:

A cold storage facility with an air-cooled condenser is being commissioned. The control system designer has used a dry bulb-following control strategy to reset the system saturated condensing temperature (SCT) set point. The refrigeration engineer has calculated that adding a TD of 11°F (6.1°C) above the ambient dry bulb temperature should provide a saturated condensing temperature set point that minimizes the combined compressor and condenser fan power usage throughout the year. What might the system SCT and SCT set point trends look like over an example day?

Answer:

The following figure illustrates the actual saturated condensing temperature and SCT set points over an example day using the dry bulb-following control strategy with an 11°F (6.1°C) TD and observing the 70°F (21°C) minimum condensing temperature requirement. As the figure shows, the SCT set point is continuously reset 11°F (6.1°C) above the ambient dry bulb temperature but is bounded by the minimum and maximum SCT set points. The figure also shows a maximum SCT set point (in this example, 90°F (32.2°C) that may be used to limit the maximum control set point, regardless of the ambient temperature value or TD parameter.



C. Condenser Specific Efficiency

§120.6(a)4F

Requirements for design condensing temperatures relative to design ambient temperatures, as described above for §120.6(a)4A, B, and C, help assure that there is enough condenser capacity to keeping condensing temperatures compressor head pressures at reasonable levels. However, the sizing requirements do not address condenser efficiency. For example, rather than providing amply sized condenser surface area, a condenser selection could consist of a small condenser area using a large motor to blow a large amount of air through the heat exchanger surface to achieve the design condenser TD. However, this would come at the expense of excessive fan motor horsepower. Also, relatively high fan power consumption can result from using condenser fans that have poor fan efficiency or low fan motor efficiency. §120.6(a)4F addresses these and other factors affecting condenser fan power by setting minimum specific efficiency requirements for condensers.

All newly installed indoor and outdoor evaporative condensers and outdoor air-cooled and adiabatic condensers to be installed on new refrigeration systems shall meet the minimum specific efficiency requirements shown in Table 10-6.

Table 10-6: Fan-Powered Condensers – Minimum Specific Efficiency Requirements

CONDENSER TYPE	REFRIGERANT TYPE	MINIMUM SPECIFIC EFFICIENCY*	RATING CONDITION
Outdoor Evaporative Cooled with THR Capacity > 8,000 MBH	All	350 Btuh/W	100°F Saturated Condensing Temperature (SCT), 70°F Outdoor Wet bulb Temperature
Outdoor Evaporative-Cooled with THR Capacity < 8,000 MBH and Indoor Evaporative-Cooled	All	160 Btuh/W	100°F Saturated Condensing Temperature (SCT), 70°F Outdoor Wet bulb Temperature
Outdoor Air-Cooled	Ammonia	75 Btuh/W	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Dry bulb Temperature
Outdoor Air-Cooled	Halocarbon	65 Btuh/W	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Dry bulb Temperature
Adiabatic Dry Mode	Halocarbon	45 Btuh/W	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Dry bulb Temperature

Indoor Air-Cooled	All	Exempt	Exempt

Source: California Energy Commission

Condenser specific efficiency is defined as:

Condenser Specific Efficiency = Total Heat Rejection (THR) Capacity / Input Power

The total heat rejection capacity is at the rating conditions of 100°F saturated condensing temperature (SCT) and 70°F outdoor wet bulb temperature for evaporative condensers, and 105°F SCT and 95°F outdoor dry bulb temperature for air-cooled condensers. Input power is the electric input power draw of the condenser fan motors (at full speed), plus the electric input power of the spray pumps for evaporative condensers. The motor power is the manufacturer's published applied power for the subject equipment, which is not necessarily equal to the motor nameplate rating. Power input for secondary devices such as sump heaters shall not be included in the specific efficiency calculation.

As shown in Table 10-6 the Energy Code has different minimum efficiencies depending on the type of condenser that is being used. The different classifications of condenser are:

a. Outdoor, evaporative, THR greater than 8,000 MBH at specific efficiency rating conditions.
b. Outdoor, evaporative, THR less than 8,000 MBH at specific efficiency rating conditions.
c. Indoor, evaporatively cooled.
d. Outdoor, air-cooled, ammonia refrigerant.
e. Outdoor, air-cooled, halocarbon refrigerant.
f. Adiabatic (dry-mode operation), halocarbon refrigerant.
g. Indoor, air-cooled.

The data published in the condenser manufacturer's published rating for capacity and power shall be used to calculate specific efficiency. For evaporative condensers, manufacturers typically provide nominal condenser capacity and tables of correction factors that are used to convert the nominal condenser capacity to the capacity at various applied condensing temperatures and wet bulb temperatures. Usually, the manufacturer publishes two sets of correction factors: one is a set of "heat rejection" capacity factors, while the others are "evaporator ton” capacity factors. Only the “heat rejection” capacity factors shall be used to calculate the condenser capacity at the efficiency rating conditions for determining compliance with this section.

For air-cooled and adiabatic condensers, manufacturers typically provide the capacity at a given temperature difference (TD) between SCT and dry bulb temperature. Manufacturers typically assume that condenser capacity is linearly proportional to TD; the catalog capacity at 20°F TD is typically twice as much as at 10°F TD. The condenser capacity for air-cooled condensers at a TD of 10°F shall be used to calculate efficiency. For adiabatic condensers, the dry mode capacity at a TD of 10°F shall be used to calculate efficiency. If the capacity at 10°F TD is not provided, the capacity shall be scaled linearly.

Depending on the type of condenser, the actual manufacturer’s rated motor power may vary from motor nameplate in different ways. Air cooled condensers with direct-drive OEM motors may use far greater input power than the nominal motor horsepower would indicate. On the other hand, evaporative condenser fans may have a degree of safety factor to allow for higher motor load in cold weather (vs. the 100°F SCT/70°F WBT specific efficiency rating conditions). Thus, actual motor input power from the manufacturer must be used for direct-drive air-cooled condensers, while for large (i.e., > 8,000 MBH) evaporative condensers and other belt-drive condensers, the full load motor rating is generally conservative, but manufacturer’s applied power should be used whenever possible to determine specific efficiency more accurately.

Example 10-49

Question

An evaporative condenser is being considered for use in an outdoor application on a new refrigerated warehouse. The refrigerant is ammonia. The condenser manufacturer's catalog provides the following information:

Model Number	Base Heat Rejection (MBH)
A441	4410
B487	4866
C500	4998
D551	5513
E559	5586
F590	5895
G591	5909
H598	5983
I631	6306
J637	6365

Condensing Temperature (°F)	Entering Wetbulb Temperature (°F)					
	62	64	66	68	70	72
95	0.88	0.92	0.97	1.02	1.08	1.16
96.3	0.84	0.88	0.92	0.97	1.02	1.09
97	0.83	0.86	0.90	0.94	0.99	1.05
98	0.80	0.83	0.87	0.91	0.96	1.01
99	0.77	0.80	0.84	0.87	0.92	0.97
100	0.75	0.78	0.81	0.84	0.88	0.93

For this example, model number D551 is being considered. Elsewhere in the catalog, it states that condenser model D551 has two 7.5 HP fan motors and one 5 HP pump motor. Fan motor efficiencies and motor loading factors are not provided. Does this condenser meet the minimum efficiency requirements?

Answer

First, the condenser capacity must be calculated at the efficiency rating condition. From Table 10-4, we see that the rating conditions for an outdoor evaporative condenser are 100°F SCT, 70°F WBT. From the Base Heat Rejection table above, we see the nominal capacity for model D551 is 5,513 MBH. From the Heat Rejection Capacity Factors table, we see that the correction factor for 100°F SCT, 70°F WBT is 0.88. The capacity of this model at specific efficiency rating conditions is 5,513 MBH / 0.88 = 6,264 MBH. Since 6,264 MBH is less than 8,000 MBH, we can see from Table10-4 that the minimum specific efficiency requirement is 160 (Btu/hr)/watt.

To calculate input power, we will assume 100% fan and pump motor loading and minimum motor efficiency since the manufacturer has not yet published actual motor input power at the specific efficiency rating conditions. We look up the minimum motor efficiency from Nonresidential Appendix NA-3: Fan Motor Efficiencies. For a 7.5 HP four-pole open fan motor, the minimum efficiency is 91.0%. For a 5 HP six-pole open pump motor, the minimum efficiency is 89.5%. The fan motor input power is calculated to be:

2 motors x 7.5 HP/motor x 746 watts/HP x 100% assumed loading/ 91% efficiency = 12.297 watts

The pump motor input power is calculated to be:

1 motors x 5 HP/motor x 746 watts/HP x 100% assumed loading/ 89.5% efficiency = 4.168 watts

The combined input power is therefore:

12.297 watts + 4.168 watts = 16.464 watts

Note: Actual motor power should be used when available (see notes in text).

Finally, the efficiency of the condenser is:

(6,264 MBH x 1000 Btuh/MBH) / 16.464 watts = 381 Btuh/watt

This condenser meets the minimum efficiency requirements because 381 Btu/hr per watt is higher than the 160 Btu/hr per watt requirement.

D. Condenser Fin Spacing

According to §120.6(a)4G air-cooled condensers shall have a fin density no greater than 10 fins per inch. Condensers with higher fin densities have a higher risk of fouling with airborne debris. This requirement does not apply to air-cooled condensers that use a microchannel heat exchange surface, since this type of surface is not as susceptible to permanent fouling in the same manner as traditional tube-and-fin condensers with dense fin spacing.

10.6.3.4 Compressors

§120.6(a)5

Compressors on new refrigeration systems must follow the design and control requirements as described in §120.6(a)5.

Floating head control is one of the largest energy savings measures applied to refrigeration systems. This control attempts to keep condensing temperatures as low as possible (while not consuming too much condenser fan energy) as this reduces compressor head pressure, which directly affects compressor energy. When ambient temperatures are low, the primary constraint on how low the condensing temperature can be reset is the design requirements of the compressor and associated system components.

§120.6(a)5A and §120.6(a)5B address the compatibility of the compressor design and components with the requirements for floating head control for compressors serving refrigeration systems other than transcritical CO_2 systems and compressors serving transcritical CO_2 systems respectively.

A. Compressors Serving Systems Other Than Transcritical CO_2

All compressors that discharge to the condenser(s) and all associated components (coalescing oil separators, expansion valves for liquid injection oil cooling, etc.) must be capable of operating at a condensing temperature of 70°F (21°C) or less. Oil separator sizing is often governed by the minimum condensing temperature, as well as other factors, such as the maximum suction temperature. Suction temperatures above the design value may occur under floating suction temperature control schemes.

The system designer should also keep in mind that other design parameters such as piping run lengths or evaporator defrost requirements must be considered to meet this requirement.

B. Compressors Serving Transcritical CO_2 Systems

All compressors that discharge to the gas cooler(s) and all associated components (coalescing oil separators, expansion valves for liquid injection oil cooling, etc.) must be capable of operating at a condensing temperature of 60°F (16°C) or less. Oil separator sizing is often governed by the minimum condensing temperature, as well as other factors, such as the maximum suction temperature. Suction temperatures above the design value may occur under floating suction temperature control schemes.

The system designer should also keep in mind that other design parameters such as piping run lengths or evaporator defrost requirements must be considered to meet this requirement.

An exception to §120.6(a)5B is provided for compressors that are designed to operate at a saturated suction temperature equal to or greater than 30°F. In this case, the compressors can be designed to operate at a minimum condensing temperature of 70°F or less.

C. Screw Compressor Control at Part-Load

New open-drive screw compressors in new refrigeration systems with a design saturated suction temperature (SST) of 28°F or lower shall vary compressor speed as the primary means of capacity control. The compressor speed shall reduce to the manufacturer-specified minimum speed before unloading via slide valve. Similarly, when the load increases, the compressor shall increase to 100 percent slide valve before increasing speed. This requirement applies only to compressors discharging to the condenser (i.e., single stage or the high stage of a two-stage system) and only to suction groups that consist of a single compressor.

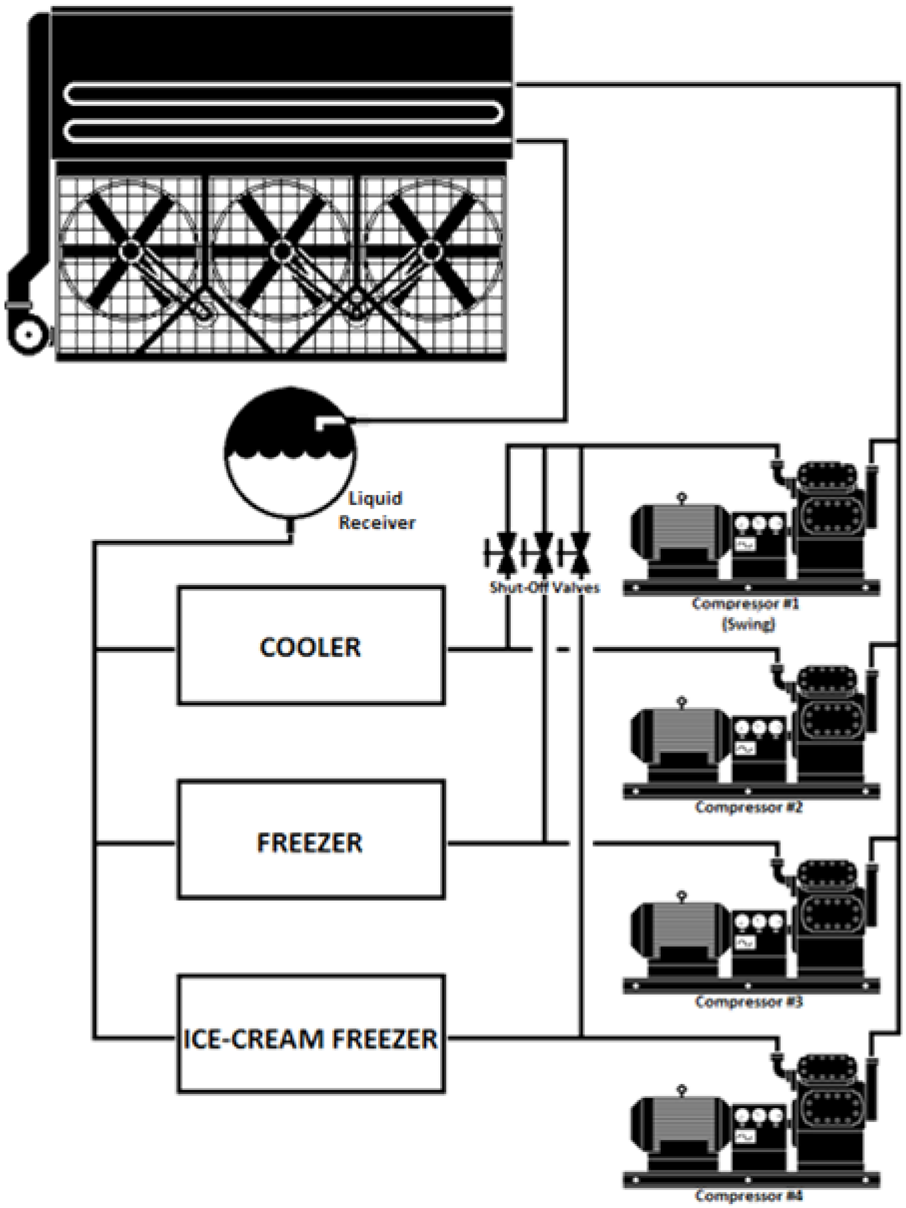
An exception to §120.6(a)5B (controlling compressor speed in response to refrigeration load) is provided for compressors on a refrigeration system with more than 20 percent of the design cooling load from quick chilling or freezing space, or nonspace process refrigeration cooling. The "refrigeration system" refers to the entire associated system, (i.e., the refrigerant charge), not the suction group. While variable-speed compressor control may be cost-effective in many instances and may be considered by the system designer, this exception exists to allow for situations such as seasonal processes with low operating hours or loads that may be precisely matched to a fully loaded compressor.

New screw compressors with a motor nameplate power greater than 150 HP shall incorporate the capability to automatically vary the volume ratio (i.e., variable Vi) to optimize efficiency at off-design operating conditions.

Example 10-50

Question

The system shown below has three 200 HP open-drive screw compressors serving three suction levels and one 200 HP backup or swing open-drive screw compressor that can be connected by valve into any of the three suction lines. Does this count as having more than one compressor per suction group and exempt the compressors from the requirements in §120.6(a)5B?



Answer

Probably not. Exception 1 to §120.6(a)5B applies only when a suction group has two or more dedicated compressors. A compressor that is used solely as backup does not count as a dedicated compressor. As a result, all compressors (1, 2, 3, and 4) in the example above must comply with §120.6(a)5B and use variable-speed control as the primary means of capacity control. However, if Compressor 1 is actually required to meet the design load of one of the suction groups, it could be considered part of that suction group and variable-speed control would not be required. Whether a swing compressor is really a backup compressor or part of a suction group should be apparent from the design loads and capacities listed in the design documents.

10.6.3.5 Acceptance Requirements

§120.6(a)7

The Energy Codes have acceptance test requirements for:

- Electric underslab heating controls.
- Evaporator fan motor controls.
- Evaporative condensers.
- Adiabatic condensers
- Air-cooled condensers.
- Variable-speed compressors.
- Transcritical CO_2 refrigeration systems.

These test requirements are described in Chapter 13 and the Reference Nonresidential Appendix NA7.10. They are described briefly in the following paragraphs.

A. Electric Underslab Heating Controls

NA7.10.1

Controls for underslab electric heating controls, when used for freeze protection on freezer floors, are tested to ensure heat is automatically turned off during summer on-peak electric periods.

B. Evaporator Fan Motor Controls

NA7.10.2

Evaporator equipment and controls are checked for proper operation. The controls are tested to ensure the fan speed automatically varies in response the temperature and/or humidity of the space.

C. Evaporative Condensers

NA7.10.3.1

Evaporative condensers and variable-speed fan controls are checked to ensure the required minimum SCT set point of 70°F or lower is implemented, and the condenser fans continuously vary in unison to maintain a target temperature difference between the SCT and the wet bulb temperature. Trends of wet bulb temperature and SCT can be used to verify the controls over time.

The condenser control TD or offset is a key parameter in fine-tuning the operation of the fans and maximizing the energy savings. In best practice, this control setting should be adjusted during average load so that the fan average 60-80% speed when in the control range (i.e., between the minimum and maximum SCT set points).

D. Air-Cooled Condensers

NA7.10.3.2

Air-cooled condensers and variable-speed fan controls are checked to ensure the required minimum SCT set point of 70°F or lower is implemented, and the condenser fans continuously vary in unison to maintain a target temperature difference between the SCT and dry bulb temperature. Trends of dry bulb temperature and SCT can be used to verify the controls over time.

The condenser control TD is a key parameter in fine-tuning the operation of the fans and maximizing energy savings. This control setting should be adjusted during average load so that condenser capacity is effectively used but fan speed is not excessive.

E. Adiabatic Condensers

NA7.10.3.3

Adiabatic condensers and variable-speed fan controls are checked to ensure the required minimum SCT set point of 70°F or lower is implemented, and the condenser fans continuously vary in unison to maintain a target temperature difference between the SCT and dry bulb temperature when operating in dry mode. Trends of dry bulb temperature and SCT can be used to verify the controls over time.

The condenser control TD is a key parameter in fine-tuning the operation of the fans and maximizing the energy savings. This control setting should be adjusted during average loaded so that condenser capacity is effectively used but fan speed is not excessive.

F. Variable-Speed Compressors

NA7.10.4

The controls and equipment for the variable-speed control of screw compressors are checked and certified as part of the acceptance requirements. The compressor should unload capacity by reducing speed to the minimum speed set point before unloading by slide valve or other means. Control system trend screens can also be used to verify that the speed varies automatically in response to the load.

10.6.3.1 G. Transcritical CO_2 Systems

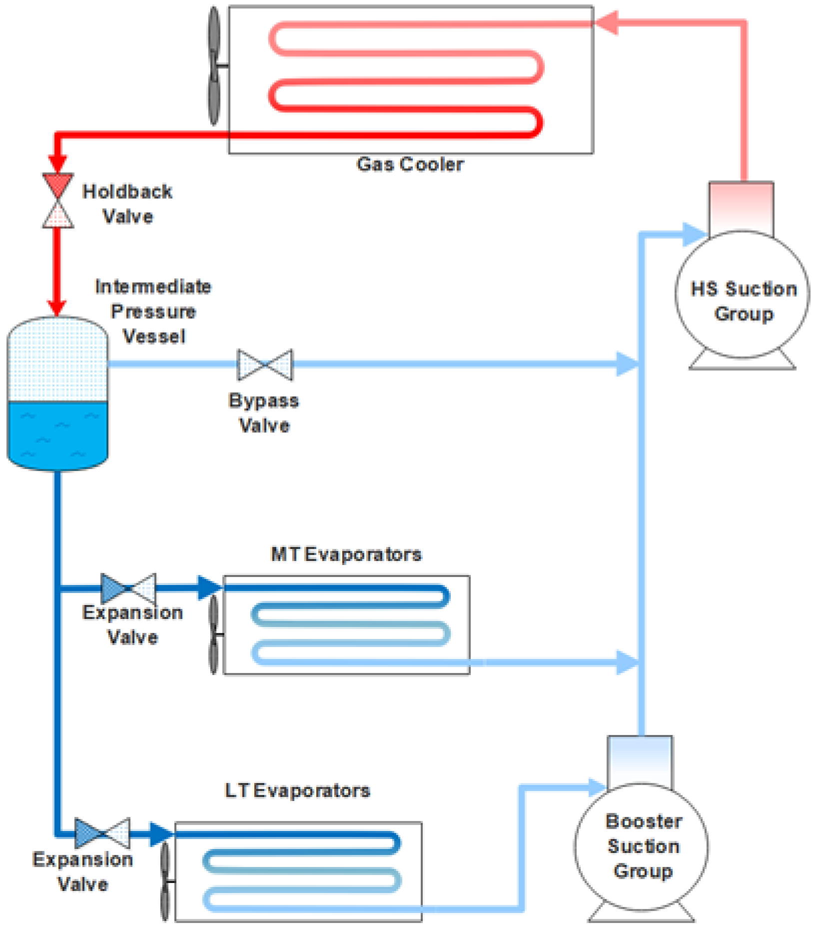
NA7.20.1

The controls and equipment of transcritical CO2 refrigeration systems are checked to verify correct operation of gas cooler controls, including testing of subcritical and supercritical operating modes.

10.6.3.2 10.6.3.2 Transcritical CO_2 Systems

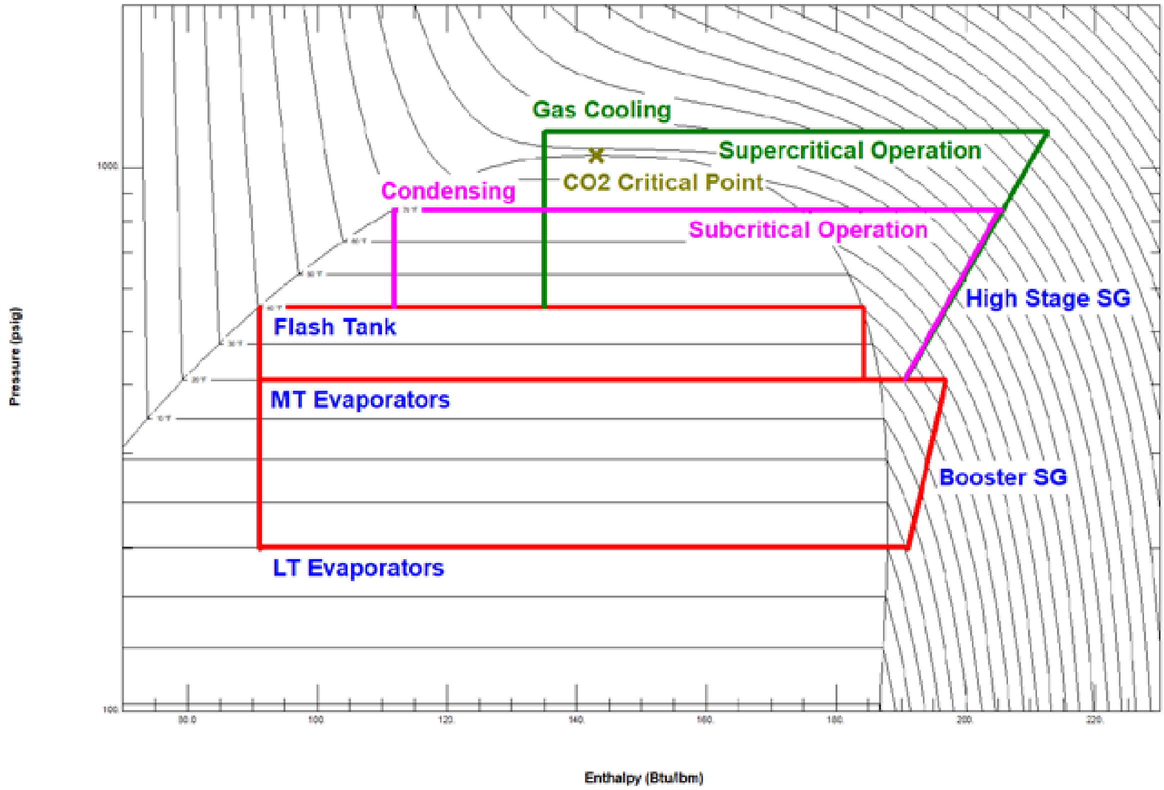
A typical transcritical CO_2 booster system is shown in Figure 10-37 below. The system consists of two suction groups: booster and high stage (HS). The compressors in the booster suction group serve low temperature (LT) loads and discharge into the suction of the high stage suction group. The compressors in the high stage suction group serve the medium temperature (MT) loads, as well as compress the gas from the booster suction group and the intermediate pressure vessel to high pressures. Heat is rejected from the high pressure gas in the gas cooler when the system is operating in supercritical mode. The discharge pressure is commonly controlled by a hold back valve in combination with the gas cooler fans. When operating in subcritical mode the gas cooler operates as a condenser, analogous to other common refrigeration systems. The gas or liquid from the gas cooler / condenser expands in the intermediate pressure vessel / flash tank. The gas from the intermediate pressure vessel is compressed by the high stage compressors, and the liquid from the flash tank is supplied to medium temperature and low temperature evaporators (loads). The evaporated gas in the evaporators is compressed by its respective suction group compressors.

Figure 10-37: Common Transcritical CO_2 System Configuration



The critical point of a substance is the point above which the liquid and vapor phases become indistinguishable from each other, forming a 'supercritical fluid'. In the supercritical region, temperature and pressure are semi-independent variables. CO_2 has a critical point of 87.8°F, which is considered to be a low critical point compared to all commonly used refrigerants. A pressure-enthalpy (PH) diagram for CO_2 with its critical point labeled is shown in Figure 10-38. In a transcritical CO_2 refrigeration system, the high stage suction group can operate both above and below the critical point. When ambient temperatures are high, above approximately 75°F, the HS suction group compresses CO_2 above its critical point and the system is said to be in supercritical operation. An example of a HS suction group supercritical vapor compression cycle on the PH diagram for CO_2 is represented in green in Figure 10-38. During lower ambient conditions, when CO_2 is below its critical point after compression, the system is said to be in subcritical operation. An example of a HS suction group subcritical vapor compression cycle on the PH diagram for CO_2 is represented in pink in Figure 10-38.

Figure 10-38: Common Transcritical CO2 System Configuration



In subcritical mode, the system operates very similarly to other refrigeration systems. In supercritical mode, the overall system efficiency decreases compared with subcritical operation. This is because high ambient temperatures result in higher compressor discharge temperatures needed for heat rejection, which increases the suction-to-discharge pressure ratio to be overcome by the compressor. Additionally, when operating in supercritical mode, the gas cooler outlet stream has a higher quality (higher vapor fraction) compared to subcritical mode. Vapor in the intermediate pressure vessel does not contribute to productive refrigeration but needs to be compressed, increasing the non-productive refrigeration load on the compressors. Available technologies that increase supercritical operation efficiency include gas ejectors and parallel compression.

10.6.3.2.1 Transcritical CO_2 Gas Coolers

§120.6(a)8

New fan-powered gas coolers on all new transcritical CO_2 refrigeration systems must follow the gas cooler type, sizing, fan control, and efficiency requirements as described in §120.6(a)8.

A. Air-cooled Gas Coolers Restrictions

§120.6(a)8A

§120.6(a)8A prohibits the use of air-cooled gas coolers in Climate Zones 9 through 15, which are high ambient temperature climate zones, to reduce the number of supercritical operating hours. Alternatives to air cooled gas coolers include water cooled gas coolers connected to a cooling tower, adiabatic gas coolers, and evaporative gas coolers.

B. Gas Cooler Sizing

§120.6(a)8B and §120.6(a)8C describe minimum sizing requirements for new gas coolers serving new transcritical CO_2 refrigeration systems. Fan-powered air-cooled gas coolers are covered by §120.6(a)8B. Fan-powered adiabatic gas coolers are covered by §120.6(a)8C.

Gas coolers must be sized to provide sufficient heat rejection capacity under design conditions while maintaining a specified maximum temperature difference between the gas cooler leaving gas temperature and ambient temperature. The design gas cooler capacity shall be greater than the calculated combined total heat of rejection (THR) of the dedicated compressors that are served by the gas cooler. If multiple gas coolers are specified, then the combined capacity of the installed gas coolers shall be greater than the calculated heat of rejection. When determining the design THR for this requirement, reserve or backup compressors may be excluded from the calculations. Example 10-50 provides an example scenario of which compressors to include in the THR calculation described in this section.

1. Air-Cooled Gas Cooler Sizing

§120.6(a)8B

§120.6(a)8B provides maximum design gas cooler leaving gas temperature (LGT) values for air-cooled gas coolers. For this section, designers should use the 0.5 percent design dry bulb temperature (DBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement.

Standard practice is for published gas cooler ratings to assume the capacity of air-cooled gas coolers is proportional to the temperature difference (TD) between the LGT and DBT, regardless of the actual ambient temperature entering the gas cooler. For example, the capacity of an air-cooled gas cooler operating at a leaving gas temperature of 80°F with a DBT of 70°F is assumed to be equal to the same unit operating at 110°F LGT and 100°F DBT, since the TD across the gas cooler is 10°F in both examples. Thus, the requirement for air-cooled gas coolers is based on the temperature difference between the DBT and gas cooler leaving gas temperature. Air cooled gas coolers shall be sized so the design leaving gas temperature for air-cooled gas coolers shall be less than or equal to the design dry bulb temperature plus 6°F.

The Energy Codes include an exception to §120.6(a)8B for air-cooled gas coolers serving refrigeration systems in Climate Zones 2, 4 and 8 where the design leaving gas temperature for shall be less than or equal to the design dry bulb temperature plus 8°F.

2. Adiabatic Gas Cooler Sizing

§120.6(a)8C

§120.6(b)8C provides maximum design gas cooler leaving gas temperature (LGT) values for adiabatic gas coolers. For this section, designers should use the 0.5 percent design dry bulb temperature (DBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement.

Standard practice is for published gas cooler ratings to assume the capacity of adiabatic gas coolers is proportional to the temperature difference (TD) between the LGT and DBT for operation in dry mode, regardless of the actual ambient temperature entering the gas cooler. For example, the capacity of an adiabatic gas cooler operating at a LGT of 80°F with a DBT of 70°F is assumed to be equal to the same unit operating at 110°F LGT and 100°F DBT during dry mode operation, since the TD across the gas cooler is 10°F in both examples. Thus, similar to air-cooled gas coolers, the requirement for adiabatic gas coolers is based on the temperature difference between the DBT and gas cooler leaving gas temperature. Design leaving gas temperature for adiabatic gas coolers necessary to reject the design total heat of rejection of a refrigeration system assuming dry mode performance shall be less than or equal to the design dry bulb temperature plus 15°F.

C. Fan Control

§120.6(a)8D through §120.6(a)8G describe fan control requirements for new gas coolers serving new transcritical CO_2 refrigeration systems. Fan speed control requirements are covered by §120.6(a)8D. Gas cooler pressure control requirements during subcritical and supercritical operation are described by §120.6(a)8E and §120.6(a)8F respectively. Minimum condensing temperature set point is covered by §120.6(a)8G.

1. Speed Control

§120.6(a)8D

Gas cooler fans for new air-cooled, evaporative-cooled or adiabatic gas coolers, or fans on cooling towers or fluid coolers used to reject heat on new transcritical CO_2 refrigeration systems, must use continuously variable-speed. Variable-frequency drives are commonly used to provide continuously variable-speed control of gas cooler fans, although controllers designed to vary the speed of electronically commutated motors may be used to control these types of motors. All fans serving a common high side, or cooling water loop for cooling towers and fluid coolers, shall be controlled in unison. Thus, in normal operation, the fan speed of all fans within a single gas cooler or set of gas coolers serving a common high side should modulate together, rather than running fans at different speeds or staging fans off. However, when fan speed is at the minimum practical level usually no higher than 10-20%, the fans may be staged off to reduce gas cooler capacity. As load increases, fans should be turned back on before significantly increasing fan speed, recognizing a control band is necessary to avoid excessive fan cycling.

2. Subcritical Pressure Control

§120.6(a)8E

§120.6(a)8E provides pressure control requirements for gas cooler operation below the critical point. These requirements are the same as for §120.6(a)4F with the exception that the minimum condensing temperature set point must be 60°F for transcritical CO_2 systems with a design intermediate saturated suction temperature lower than 30°F. See section 10.6.3.3. B for details.

3. Supercritical Pressure Control

§120.6(a)8F

During supercritical mode, the gas cooler pressure set point must be continuously reset in response to ambient conditions to optimize system efficiency, rather than using a fixed set point value.

Specifying the exact relationship to be used to determine the optimal head pressure may be dependent on multiple variables beyond ambient air temperature, including the operating saturated suction temperature, system configuration, gas cooler technology type, and current load. The controls manufacturer shall consider the tradeoff between fan energy and compressor energy in developing a pressure and fan control that is responsive to environmental and system conditions.

4. Minimum SCT Set point

§120.6(a)8G

The minimum saturated condensing temperature set point must be 60°F (16°C) or less for air-cooled gas coolers, evaporative-cooled gas coolers, adiabatic gas coolers, air or water-cooled fluid coolers or cooling towers. As a practical matter, a maximum condensing temperature set point is also commonly employed to set an upper bound on the control set point in the event of a sensor failure and to force full gas cooler operation during peak ambient conditions. This value should be set high enough that it does not interfere with normal operation.

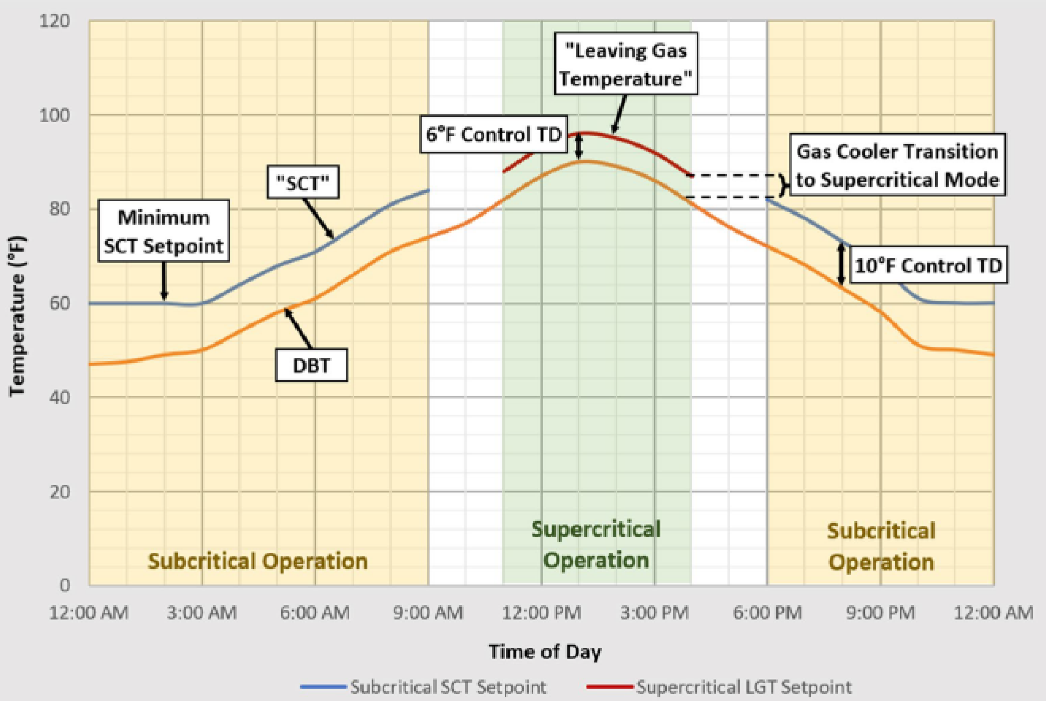
Example 10-50

Question

A refrigerated warehouse with air-cooled gas coolers serving freezers is being commissioned. The control system designer has used a drybulb-following control strategy to reset the system saturated condensing temperature (SCT) setpoint when the system is operating subcritically, with a TD of 10°F (5.6°C) above the ambient drybulb temperature. The control system designer has used a proprietary gas cooler pressure control strategy to maximize system efficiency by minimizing the combined compressor and condenser fan power usage when the system is operating supercritically, with a TD of 6°F (3.3°C). What might the system DBT and SCT / gas cooler leaving gas temperature (LGT) setpoints trends look like over an example day?

Answer

The following figure illustrates what the actual SCT / LGT setpoint could be over an example day using the drybulb-following control strategy with a 10°F TD (5.6°C) when operating subcritically, a 6°F (3.3°C) TD when operating supercritically and observing the 60°F (16°C) minimum condensing temperature requirement. As the figure shows, the SCT setpoint is continuously reset to 10°F (5.6°C) above the ambient drybulb temperature until the minimum SCT setpoint of 60°F (16°C) is reached when operating subcritically and 6°F (3.3°C) above the ambient drybulb temperature when operating supercritically.



D. Gas Cooler Specific Efficiency

§120.6(a)8H

Requirements for design leaving gas temperatures relative to design ambient temperatures, as described above for §120.6(a)8B and C, help assure that there is enough gas cooler capacity to keep leaving gas temperatures compressor head pressures at reasonable levels. However, the sizing requirements do not address gas cooler efficiency. For example, rather than providing amply sized gas cooler surface area, a gas cooler selection could consist of a small gas cooler area using a large motor to blow a large amount of air through the heat exchanger surface to achieve the design gas cooler TD. However, this would come at the expense of excessive fan motor horsepower. Also, relatively high fan power consumption can result from using gas cooler fans that have poor fan efficiency or low fan motor efficiency. §120.6(a)8H addresses these and other factors affecting gas cooler fan power by setting minimum specific efficiency requirements for gas coolers.

Table 10-7: Transcritical CO_2 Fan-Powered Gas Coolers – Minimum Specific Efficiency Requirements

Condenser Type	Refrigerant Type	Minimum Specific Efficiency	Rating Condition
Outdoor Air-Cooled	Transcritical CO_2	160 Btuh/Watt	1400 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature
Adiabatic Dry Mode	Transcritical CO_2	90 Btuh/Watt	1100 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature

Condenser specific efficiency is defined as:

Condenser Specific Efficiency = Total Heat Rejection (THR) Capacity / Input Power

The total heat rejection capacity is at the rating conditions of 100°F outlet gas temperature and 90°F outdoor dry bulb temperature. Input power is the electric input power draw of the gas cooler fan motors (at full speed). The motor power is the manufacturer's published applied power for the subject equipment, which is not necessarily equal to the motor nameplate rating. Power input for secondary devices shall not be included in the specific efficiency calculation.

As shown in Table 10-7 the Energy Code has different minimum efficiencies depending on the type of gas cooler that is being used. The different classifications of gas coolers are:

1. Outdoor, air-cooled.
2. Adiabatic (dry-mode operation).

The data published in the gas cooler manufacturer's published rating for capacity and power shall be used to calculate specific efficiency.

For air-cooled and adiabatic gas coolers, manufacturers typically provide the capacity at a given temperature difference (TD) between SCT and dry bulb temperature. Manufacturers typically assume that gas cooler capacity is linearly proportional to TD; the catalog capacity at 20°F TD is typically twice as much as at 10°F TD. The gas cooler capacity for air-cooled gas cooler at a TD of 10°F shall be used to calculate efficiency. For adiabatic gas coolers, the dry mode capacity at a TD of 10°F shall be used to calculate efficiency. If the capacity at 10°F TD is not provided, the capacity shall be scaled linearly.

Depending on the type of gas cooler, the actual manufacturer's rated motor power may vary from motor nameplate in different ways. Air-cooled gas coolers with direct-drive OEM motors may use far greater input power than the nominal motor horsepower would indicate. Thus, actual motor input power from the manufacturer must be used for direct-drive air-cooled gas coolers.

Example 10-48 provides an example calculation for the efficiency of a condenser, which is analogous to how the efficiency for a gas cooler would be calculated.

10.6.4 Additions and Alterations

Requirements

Requirements related to refrigerated warehouse additions and alterations are covered by the Energy Code in §141.1(a). The specific requirements for additions and alterations for commercial refrigeration are included in §120.6(a). Definitions relevant to refrigerated warehouses include the following:

An **addition** is a change to an existing refrigerated warehouse that increases refrigerated floor area and volume. Additions are treated like new construction.

When an unconditioned or conditioned building or an unconditioned or conditioned part of a building adds refrigeration equipment so that it becomes refrigerated, this area is treated as an addition.

An **alteration** is a change to an existing building that is not an addition or repair. An alteration could include installing new evaporators, a new lighting system, or a change to the building envelope, such as adding insulation.

A **repair** is the reconstruction or renewal of any part of an existing building or equipment for maintenance. For example, a repair could include the replacement of an existing evaporator or condenser.

Any addition or altered space must meet all applicable mandatory requirements. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered an alteration.

Example 10-51

Question

The new construction is an addition to an existing refrigerated warehouse. The new space is served by an existing refrigeration plant. Does the refrigeration plant need to be updated to meet the Energy Code?

Answer

No. The new construction must comply with the Energy Code; however, the existing refrigeration plant equipment is exempt from the Energy Code.

Example 10-52

Question

The new construction includes an addition to refrigerated space and expansion of the existing refrigeration plant. Is the existing refrigeration equipment subject to the Energy Code?

Answer

No. Only the new equipment installed in the added refrigerated space and any new compressors added to the existing plant are subject to the requirements of the Energy Code. If a new refrigeration system was installed with a new condenser for the addition, then the new condenser must also comply with the Energy Code.

Example 10-53

Question

An upgrade to an existing refrigerated storage space includes replacing all of the existing evaporators with new evaporators. Do the new evaporators need to comply with the Energy Code?

Answer

Yes. A complete renovation of the evaporators in the space is considered an alteration. The alteration requirements apply when all the evaporators in the space are changed.

Example 10-54

Question

An existing refrigerated storage space is adding additional evaporators to meet an increase in the refrigeration load. Do the new evaporators need to comply with the Energy Code?

Answer

No. The alteration requirements apply only when all of the evaporators in the space are changed.

Example 10-55

Question

An existing evaporator is being replaced by a new evaporator as part of system maintenance. Does the new evaporator need to comply with the Energy Code?

Answer

No. Replacement of an evaporator during system maintenance is considered a repair. However, the energy consumption of the new evaporator must not exceed that of the equipment it replaced.

10.7 Laboratory Exhaust

10.7.1 Overview

§140.9(c) sets the minimum requirements for laboratory and factory exhaust systems. Laboratories have an average annual energy intensity 10-20 times larger than offices when normalized by building area. The primary drivers of laboratory building energy are long operation hours, exhaust fan energy, and makeup air conditioning in addition to typically high internal loads.

To help reduce laboratory and factory energy use, there are four categories of exhaust energy saving measures:

- Exhaust and makeup air reduction
- Reduction of conditioned makeup air
- Exhaust fan power reduction
- Fume hood automated sash closures

Laboratories in healthcare facilities are not required to meet the requirements of §140.9(c).

10.7.2 Mandatory Measures

There are no mandatory measures specific to laboratory exhaust, but the equipment efficiencies in §110.1 and §110.2 apply.

10.7.3 Prescriptive Measures

Summary of measures contained in this section:

k. Airflow Reduction Requirements - §140.9(c)1

l. Exhaust System Transfer Air - §140.9(c)2

m. Fan System Power Consumption - §140.9(c)3

n. Fume Hood Automatic Sash Closure - §140.9(c)4

10.7.3.1 Airflow Reduction Requirements

§140.9(c)1 requires that all laboratory exhaust with minimum circulation rates of 10 air changes per hour (ACH) or lower shall be designed for variable-volume control on the supply, fume exhaust, and general exhaust. This requirement will enable the system to reduce zone exhaust and makeup airflow rates to the minimum allowed for ventilation or to maintain the required differential pressure for the zone.

An exception is provided for laboratory exhaust systems where constant volume is required by code, the authority having jurisdiction (AHJ), or the facility environmental health and safety (EH&S) division [Exception 1 to §140.9(c)1]. Examples include hoods using perchloric acid, hoods with radio isotopes, and exhaust systems conveying dust or vapors that need a minimum velocity for containment.

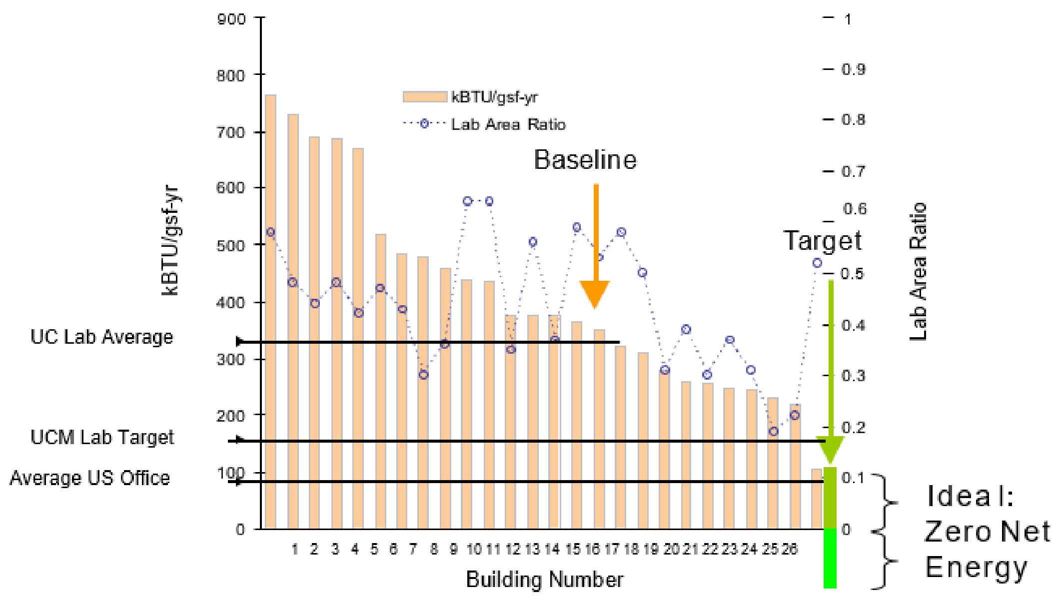
A second exception is provided for new zones added to an existing constant volume exhaust system [Exception 2 to §140.9(c)1].

The energy and demand savings depend strongly characteristics of the facility, including:

1. Ratio of lab to non-lab space.
2. Minimum airflow required by code or the facility EH&S department. These range from 4 to 18 ACH or higher.
3. Climate zone.

Figure 10-38 shows benchmarking data from Labs 21 for lab buildings in the San Francisco Bay Area. The total energy use intensity in kBtu/gsf/yr is shown on the left axis. The 26 labs are arranged from highest to lowest normalized energy use. The right axis is the "Lab Area Ratio," the ratio of lab area to total building area. There are three reference lines on this graph: The University of California campus wide average laboratory building end-use intensity, the University of California, Merced, campus goal for its laboratories; and the average national energy end use for office buildings.

Figure 10-38: Laboratory Benchmarking from Labs 21 for San Francisco Bay Area



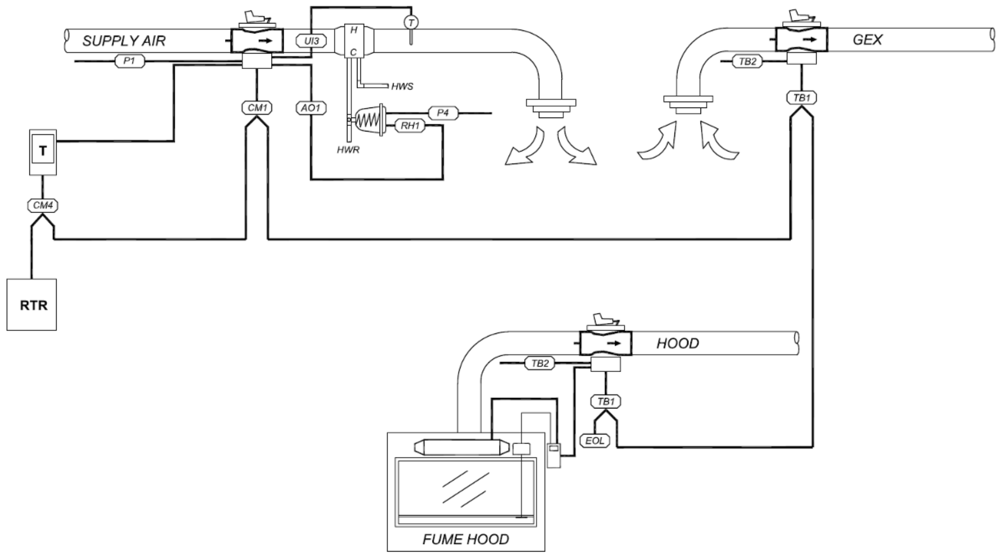
Using the criteria for cost-effectiveness in the Energy Code and very conservative estimates of the first costs (using costs from VAV retrofits not new construction), this measure was shown to be cost-effective in all California climate zones up to 14 ACH of minimum ventilation

Using off-the-shelf variable air volume (VAV) controls can greatly reduce the energy use in laboratory buildings. The Energy Code requires VAV controls on all zones not required to be constant volume by the AHJ, facility EH&S department, or other applicable health and safety codes. Furthermore, ANSI/AIHA Z9.5 and NFPA 45 allow lower minimum airflows for many hoods, which increases the savings from VAV design.

Figure 10-39 below shows the zone components for a VAV laboratory. There are three zone valves shown in this image: one each on the supply air to the zone, the fume hood (if one exists), and the general exhaust valve (GEX) if one is needed. These zone valves can be venturi type valves as shown in this image or standard dampers like those used for VAV boxes in offices. The dampers or venturi valves must be designed to resist corrosion and damage from the exhaust. When used, the hood valve is controlled to automatically maintain the design sash face velocity as the hood sash is opened or closed. The role of the supply valve is to maintain space pressurization by tracking the sum of the hood and general exhausts in the space. The supply valves are typically provided with reheat coils to maintain space comfort for heating. The GEX is typically used to control the cooling, on a call for cooling it opens, and the supply valve, in turn, opens to maintain space pressure. In some systems the supply modulates like a typical VAV box in response to the thermostat, and the GEX modulates to maintain space pressure.

All three valves are made to control either variable volume or constant volume depending on the application. A hood might for instance be required to maintain constant volume for dilution. If this is the case, a constant volume bypass hood should be employed. Even with a constant volume hood, you will need a pressure independent hood valve if the attached exhaust also serves variable-volume zones. The same rule applies for constant volume supply or general exhaust. If any zone on a supply or exhaust duct is variable volume, all zone ducts on it must have pressure independent controls.

Figure 10-39: Zone Components for a VAV Lab



The fume exhaust is generally blown out of a stack. The design of the stack and the velocity of the discharge are selected to disperse all contaminants so that they are sufficiently dilute by the time they are near any occupants. For contaminants like radio isotopes for which there is no acceptable level of dilution, the exhaust system typically has some form of filtration that captures the particles of concern. On general lab exhaust, there is typically an inlet bypass damper on the exhaust fan that modulates to keep a constant volume of exhaust moving at the stacks. Using multiple stacks in parallel, you can stage off stacks and fans to save more energy.

10.7.3.2 Exhaust System Transfer Air

This section limits the amount of conditioned air supplied to a space with mechanical exhaust. The benefit of this requirement is to take advantage of available transfer air. By doing so, the amount of air that needs to be conditioned is limited, thus saving energy. Conditioned supply air is limited to the greater of:

1. The supply flow required to meet the space heating or cooling load.
2. The ventilation rate required by the AHJ, facility EH&S department, or by §120.1(c)3.

3. The mechanical exhaust flow minus the available transfer air.

The supply flow required to meet the space heating or cooling loads can be documented by providing load calculations.

Available transfer air can be from adjacent conditioned spaces or return air plenums that are on the same floor, same smoke or fire compartment, and within 15 feet. To calculate the available transfer air:

1. Calculate the minimum outside air required by adjacent spaces.
2. From 1, subtract the amount of air required by adjacent space exhaust.
3. From 2, subtract the amount of air required to maintain pressurization of adjacent spaces. This is your available transfer air.

Exceptions are provided for:

4. Laboratories classified as biosafety level 3 or higher.
5. Vivarium spaces.
6. Spaces required to maintain positive pressure differential relative to adjacent spaces.
7. Spaces that require a negative pressure relationship and the demand for transfer air may exceed the available transfer airflow rate.
8. Healthcare facilities.

10.7.3.3 **Fan System Power Consumption**

Newly installed laboratory and factory exhaust systems greater than 10,000 CFM have three prescriptive pathways to show compliance with this section. Regardless of the path chosen, all exhaust systems must meet the discharge requirements of ANSI Z9.5.

ANSI Z9.5-2012 Discharge Requirements:

Section 5.4 and Appendix 3 of ANSI Z9.5, Laboratory Ventilation, describe standards for laboratory exhaust system design including the discharge requirements cited by this section of the Energy Code.

10.7.3.4 **Exhaust Fan System Power Consumption:**

As described in greater detail for the previous VAV section, one of the major drivers of laboratory and factory energy is fan power. To reduce this demand, three prescriptive pathways have been added for the 2019 code cycle. The first and simplest pathway is an exhaust system power limit of 0.65 or 0.85 W/cfm depending on system design. The other two options do not limit exhaust system power, but instead require exhaust volume flow rate control based on either local wind conditions or exhaust chemical concentration.

Option 1: Exhaust System Efficacy:

- Systems without air treatment devices are limited to 0.65 W/cfm of exhaust air.
- Systems with air filtration, scrubbers, or other air treatment devices are limited to 0.85 W/cfm of exhaust air.
- An exception is provided for systems with code required air treatment devices that cause static pressure drop greater than 1 inch of water. For example, a local jurisdiction which has an ordinance for high exhaust filtration, which causes high filter static pressure, due to smell or other exhaust considerations.

Option 2: Wind-Based Exhaust Volume Flow Rate Control:

This compliance path saves fan energy by reducing exhaust stack airflow when local wind conditions permit. The Energy Code, ANSI Z9.5, and other best engineering practices dictate several necessary components to this type of system:

1. Anemometer Sensors:

   a. Two anemometer sensors must be used to enable sensor fault detection.

   b. Installation location must exhibit similar wind speed and direction to the free stream air above the exhaust stacks.

   c. Sensors must be located high enough to be above the wake region created by nearby structures.

   d. Sensors must be factory calibrated.

   e. Sensors must be certified by the manufacturer to an accuracy of ± 40 feet per minute (fpm), ± 5.0 degrees, and to require calibration no more than every five years.

2. Dispersion Modeling:

   a. Wind dispersion analysis must be used to create a look-up table for exhaust volume flow rate versus wind speed/direction.

   b. Look-up table must contain at least eight wind speeds and eight wind directions to define the safe exhaust volume flow rate.

   c. Exhaust volume flow rate must be based on maintaining downwind chemical concentrations below health and odor limits as defined by the 2018 American Conference of Governmental Industrial Hygienists, Threshold Limit Values and Biological Indices, or more stringent, local, state, and federal limits if applicable.

3. Sensor Fault Management:

a. Minimum sensor failure thresholds:

- If any sensor has not been calibrated within the associated calibration period.
- Any sensor that is greater than ±30% of the four-hour average reading for all sensors.

b. Upon sensor failure, the system must revert to a safe exhaust volume flow rate based on worst-case wind conditions. Furthermore, the system must report the fault to an Energy Management Control System or other application which notifies a remote system provider.

4. Certification of requirements listed in NA7.16 for wind speed/direction control

Option 3: Contaminant Concentration-Based Exhaust Volume Flow Rate Control:

This compliance path saves fan energy by reducing exhaust airflow when the exhaust contaminant concentration is low enough to maintain safe downwind concentrations. The Energy Standards and best engineering practices dictate several necessary components to this type of system:

1. Chemical Concentration Sensors:

- Two contaminant concentration sensors must be used in each exhaust plenum to enable sensor fault detection.
- Sensors must be photo ionization detectors.
- Sensors must be factory calibrated.
- Sensors must be certified by the manufacture to an accuracy of ± 5% and require calibration no more than every six months.

2. Dispersion Modeling:

- Wind dispersion analysis must be used to determine contaminant-event thresholds (contaminant concentration levels), which control when the exhaust volume flow rate can be turned down during normally occupied hours.
- Exhaust volume flow rate must be based on maintaining downwind chemical concentrations below health and odor limits as defined by the 2018 American Conference of Governmental Industrial Hygienists, Threshold Limit Values and Biological Indices, or more stringent, local, state, and federal limits, if applicable.

3. Sensor Fault Management:

- Minimum sensor failure thresholds:
  - If any sensor has not been calibrated within the associated calibration period.
  - Any sensor that is greater than ±30% of the four-hour average reading for all sensors.
- Upon sensor failure, the system must revert to a safe exhaust volume flow rate based on worst-case wind conditions. Moreover, the system must report the fault to an energy management control system or other application that notifies a remote system provider.

- Certification of requirements listed in NA7.16 for contaminant control

Example 10-56

Question

A laboratory space has 2,500 ft^2 of conditioned floor area, a drop ceiling for plenum space, and ceiling height of 10 feet. The lab has a minimum ventilation rate of 2,500 cfm.

Is this laboratory required to have variable-volume exhaust and makeup air flow to comply with Section 140.9(c)1?

Answer

In the absence of any other code or environmental health & safety requirement for constant speed operation, Section 140.9(c)1 requires that laboratories have variable-volume exhaust and makeup airflow if the minimum ACH is less than or equal to 10. For this laboratory space, ACH is equal to the following, noting that ACH is calculated for laboratory conditioned space not including plenum volume:

ACH = 2,500 cfm x 60 min / hr / (2,500 ft^2 x 10 ft) = 6 ACH

Thus, if there is no conflicting code or safety requirement for constant volume operation, this space requires a variable-volume HVAC system.

Example 10-57

Question

A variable-volume supply fan and a variable-volume exhaust fan serving a lab system has a fan system design supply airflow and design exhaust airflow of 8,000 cfm. The system consists of one supply fan operating at an input power of 5.0 bhp and one exhaust fan operating at an input power of 8.0 bhp. The exhaust system uses a 0.6 in. pressure drop filtration device, airflow control devices, and serves fume hoods.

Does this fan system comply with the fan power requirements in Title 24?

Answer

For laboratory exhaust systems with total flow rates less than or equal to 10,000 cfm, the total fan energy of the space conditioning system and the laboratory exhaust system must comply with Section 140.4(c). First, the design fan power must be calculated in bhp, as shown below:

Design Fan Power = 5.0 bhp + 8.0 bhp = 13.0 bhp

Then, the fan power limit in section 140.4(c) is determined. From Table 140.4-A, the allowable system input power for the system is:

bhp = CFMs × 0.0013 + A

= 8,000 × 0.0013 + A = 10.4 + A

where A accounts for pressure drop adjustments.

From Table 140.4-B, the pressure drop adjustment for the exhaust flow control device (FC) is 0.5 in. of water, the pressure drop adjustment for fully ducted exhaust systems (DE) is 0.5 in. of water, and the pressure drop adjustment for the fume hoods (FH) is 0.35 in. of water. The pressure drop adjustment for fully ducted exhaust systems is included because laboratory exhaust systems are required under Title 8 to be fully ducted. An additional pressure drop adjustment is allowed to be equal to the design pressure drop of an exhaust filtration device (FD) which for this design is 0.6 in. of water column. The airflow through all these devices is 8,000 cfm, so the additional input power that is allowed is 3.8 bhp, as calculated below.

$A = [CFM_{FC} \times PD_{FC} + CFM_{DE} \times PD_{DE} + CFM_{FH} \times PD_{FH} + CFM_{FD} \times PD_{FD}] / 4{,}131$

A = [8,000 × 0.5 + 8,000 × 0.5 + 8,000 x 0.35 + 8,000 x 0.6] / 4131 = 3.8 bhp

The total allowed input power is 10.4 bhp plus 3.8 bhp, or 14.2 bhp. Because the design fan power of 13.0 bhp is less than 14.2 bhp, the system does comply using the procedure in section 140.4(c). If the system did not comply, one could evaluate several methods of dropping the design brake horsepower such as: lowering pressure drop though the system by increasing duct size or selecting low pressure drop valves or low pressure drop duct fittings. Alternatively, brake horsepower can be dropped by selecting a fan with higher fan efficiency at the design point.

Example 10-58

Question

A variable-volume supply fan and a variable-volume exhaust fan serving a lab system has a fan system design supply airflow and design exhaust airflow of 12,000 cfm. The system consists of one supply fan operating at an input power of 10.0 bhp served by a nominal 15 hp motor and one exhaust fan operating at an input brake horsepower of 18.0 bhp served by a nominal 25 hp motor, which at design conditions draws 14.4 kW. The exhaust system uses a 0.6 in. pressure drop filtration device and airflow control devices and serves fume hoods.

Does this fan system comply with the fan power requirements in Title 24?

Answer

For laboratory exhaust systems with total flow rates greater than 10,000 cfm, the fan energy of the space conditioning system is regulated by the requirements of Section 140.4(c) and the fan energy of the laboratory exhaust system is regulated by Section 140.9(c)3.

For laboratory exhaust systems with total flow rates greater than 10,000 cfm, the fan energy of the space conditioning system is regulated by the requirements of Section 140.4(c) and does NOT include the design exhaust fan power or the pressure drop adjustment credits for:

– Exhaust systems required by code or accreditation standards to be fully ducted.

– Exhaust airflow control devices.

– Exhaust filters, scrubbers, or other exhaust treatment.

– Exhaust systems serving fume hoods.

– Biosafety cabinets.

The fan power limit in Section 140.4(c) is determined. From Table 140.4-A, the allowable system input power for the system can be calculated for either the design motor horsepower for the fan or the brake horsepower supplied to the fan.

For the motor horsepower approach for a variable-volume system, with maximum design airflow rate, cfm_s, of 12,000 cfm, the nominal horsepower shall be no greater than:

$$hp < cfm_s \times 0.0015 = 12{,}000 \times 0.0015 = 18 \text{ hp}$$

The supply fan had a nominal horsepower of 15 hp. The space conditioning system passes using this approach.

For the fan brake horsepower approach in Section 140.4(c), the allowable system input power for the space conditioning system is:

$$bhp = CFMs \times 0.0013 + A$$

where A accounts for pressure drop adjustments.

In this case, there are no fan pressure adjustments as all the exhaust system and fume hood credits are accounted for in the allowances to Section 140.9(c)3.

$$\text{Allowable fan brake horsepower} = CFMs \times 0.0013 = 12{,}000 \times 0.0013 = 15.6 \text{ bhp.}$$

The supply fan had a design brake horsepower of 10.0 bhp, and since this design is less than 15.6 bhp, the space conditioning system passes using this approach.

The second half of this calculation is to determine whether the fan power of the laboratory exhaust systems complies with the requirements in Section 140.9(c)3. As given from the design documents, the exhaust fan draws 14.4 kW during design conditions while moving 12,000 cfm of air. The design fan watts per cfm is:

Design Exhaust Fan W/CFM = 14.4 kW x 1,000 W/kW / 12,000 CFM = **1.2 W/CFM**

As described in Section 140.9(c)3B, an exhaust system with an air filtration device will have a maximum allowable exhaust fan power of 0.85 W/CFM. Therefore, the maximum allowable exhaust fan power for this system is **0.85 W/CFM**. This is less than the fan system input power of 1.2 W/CFM. Therefore, the system does not comply with the fan power of Section 140.9(c)3B. The designer could redesign the system for lower design watts per cfm by increasing the height of the stack or alternatively design the system to vary the flow rate from the exhaust stack in response to wind speed in accordance with Section 140.9(c)3C or vary the flow rate from the exhaust stack in response to measured contaminant concentration in the exhaust plenum in accordance with Section 140.9(c)3D.

10.7.3.5 Fume Hood Automatic Sash Closure

10.7.3.6 Fume hood intense laboratories with VAV HVAC systems and vertical fume hood sashes are prescriptively required to install automatic sash closure systems. This measure saves energy by reducing laboratory exhaust air and makeup air conditioning. For this measure, fume hood intense means the air change rate of the space is driven by the fume hood exhaust, not minimum ventilation requirements. See Table 10-4 below, which specifies fume hood intensity by linear hood density and minimum ventilation air change rate.

10.7.3.7 The Energy Code and best engineering practices dictate several necessary components to this type of system:

1. Zone Presence Sensors:
    - Each sash closure system must have a dedicated zone presence sensor that detects people near the fume hood. Sensor should not be triggered by movement in adjacent zones.
2. Sash should automatically close within 5 minutes of sensing no presence within the fume hood zone.
3. Sash closure system safeguards:
    a. Sash automatic closing should stop when no more than 10 lbs is detected.
    b. Sash should have obstruction sensors that can detect obstructions, including transparent materials such as glassware.
4. Sash closure system must be configurable in a manual open mode.
    1. Manual open mode requires user input (push button, pedal, etc.) to open the sash and will not open automatically from presence detection.
    2. This mode is important for two reasons:
        - Safety: One example is a fume hood that has cross traffic that could cause inadvertent opening in automatic mode. This unnecessarily exposes occupants to dangerous chemicals.
        - Energy Savings: In general, a manual open configuration will save the most energy because the hood is only intentionally opened. Automatic opening mode could cause the sash to open unnecessarily, and fume hoods use more energy when fully open.

3. Automatic closing is unaffected by manual open mode
4. The Energy Code only requires the option of manual mode; sashes can still be configured in auto open mode, if preferred.

5. Certification of requirements listed in NA7.17

10.7.3.8 Fume Hood Intense Laboratories:

10.7.3.9 The intention of the fume hood intense definition is to only require automatic sash closures for spaces that have ventilation driven by fume hood exhaust, not minimum outdoor air requirements. With regard to this table, *linear feet of fume hoods* refer to the nominal hood width, not the sash opening width. The following table defines all spaces that qualify as fume hood intense:

Table 10-4: Fume Hood Intensive Laboratories

Occupied Minimum Ventilation ACH	≤ 4	> 4 and ≤ 6	> 6 and ≤ 8	> 8 and ≤ 10	> 10 and ≤ 12	> 12 and ≤ 14
Hood Density (linear feet per 10,000 ft^3 of laboratory space)	≥ 6	≥ 8	≥ 10	≥ 12	≥ 14	≥ 16

Source: California Energy Commission

Example 10-59

Question

A variable-volume laboratory space has two rooms with 10-foot ceilings, both of which have minimum ventilation rates of 6 ACH. One room has two 6-foot fume hoods and a floor area of 1,000 square feet. The second room has three 6-foot fume hoods and a floor area of 2,500 square feet.

Which fume hoods are required to have automatic sash closing controls, according to Section 140.9(c)4?

Answer

For each space, determine the fume hood density (FHD) as calculated below, noting that hoods of any sash type contribute to the nominal hood length.

FHD = 10,000 ft3 x Total nominal hood length / (lab space volume)

FHD1000 = 10,000 ft3 x 2 x 6 feet / (1,000 ft2 x 10 ft) = 12

FHD2500 = 10,000 ft3 x 3 x 6 feet / (2,500 ft2 x 10 ft) = 7.2

Using the column for minimum ventilation rate of 6 ACH in reference Table 140.9-B, fume hood densities greater than or equal to 8 are fume hood intensive. Since the 1,000 ft2 room is fume hood intensive, any hoods with vertical only sashes in that space are covered by the automatic sash closing controls prescriptive requirement. Since the 2,500 ft2 room is not fume hood intensive, that space is not required to have sash closing controls.

Example 10-60

Question

A building has two laboratory spaces with fume hoods, one with a minimum ventilation rate of 8 ACH and one with a minimum ventilation rate of 12 ACH. Both are designed to have variable-volume HVAC systems even though Section 140.9(c) only requires variable air volume when minimum ACH is 10 or less.

Which fume hoods are required to have automatic sash closing controls, according to Section 140.9(c)4?

Answer

If the spaces are deemed to be fume hood intensive according to Table 140.9-B for the corresponding minimum ACH, they are required to have sash closing controls on any vertical sash hoods. Automatic sash closing controls are required for any vertical-only hoods in fume hood intensive spaces in variable-volume laboratories.

10.7.4 Additions and Alterations

Variable Exhaust and Makeup Airflow

As noted in the previous, section variable volume controls are not required if you are adding zones to an existing constant volume system.

Exhaust System Transfer Air

Additions and alterations must comply with the requirements of this section. For alterations, this means that any additional exhaust and conditioned air resulting from an alteration must comply with this section.

Fan System Power Consumption

All newly installed exhaust systems greater than 10,000 cfm must meet the requirements of this section. Alterations and additions that increase an existing exhaust system’s airflow rate over the 10,000-cfm threshold do not need to meet the requirements.

Fume Hood Automatic Sash Closure

Additions and alterations must meet the requirements of this section. The addition of fume hoods to a space resulting in a density above the values of Table 140.9-B requires compliance with this section for those newly installed fume hoods.

10.8 Compressed Air Systems

10.8.1 Overview

Section 120.6(e) applies to all new compressed air systems and all additions or alterations to a compressed air system with a total installed compressor capacity ≥ 25 hp. An exception is given for medical gas compressed air systems serving healthcare facilities.

Key terms and definitions:

A. **Trim compressor:** a compressor that is designated for part-load operation, handling the short-term variable trim load of end uses, in addition to the fully loaded base compressor. In general, the trim compressor will be controlled by a VSD, but it also can be a compressor with good part-load efficiency. If the trim compressor does not have good part load efficiency broadly across the operating range, then it will take more compressors to meet the Energy Code requirements.

B. **Base compressor:** the opposite of a trim compressor, a base compressor is expected to be mostly loaded. If the compressed air system has only one compressor, the requirements of the Energy Code requires that the single compressor be treated as a trim compressor.

C. **Specific power:** the ratio of power to compressed air flow rate at a given pressure typically given in units of kW/100 acfm. The lower the specific power, the more efficient the compressor is at a given compressed air load.

D. **Total effective trim capacity:** the combined effective trim capacity of all trim compressors where effective trim capacity for each compressor is the range of capacities in acfm, which are within 15 percent of the specific power at the most efficient operating point. This is displayed in Figure 10-42.

E. **Largest net capacity increment:** the largest increase in capacity when switching between combinations of base compressors that is expected to occur under the compressed air system control scheme. See Example 10-54.

F. **Primary Storage:** tanks or other devices that store compressed air. Also known as an air receiver, they reduce peak air demand on the compressor system and reduce the rate of pressure change in a system. As primary storage, these devices are near the air compressors and are differentiated from remote storage that might be near an end-use device.

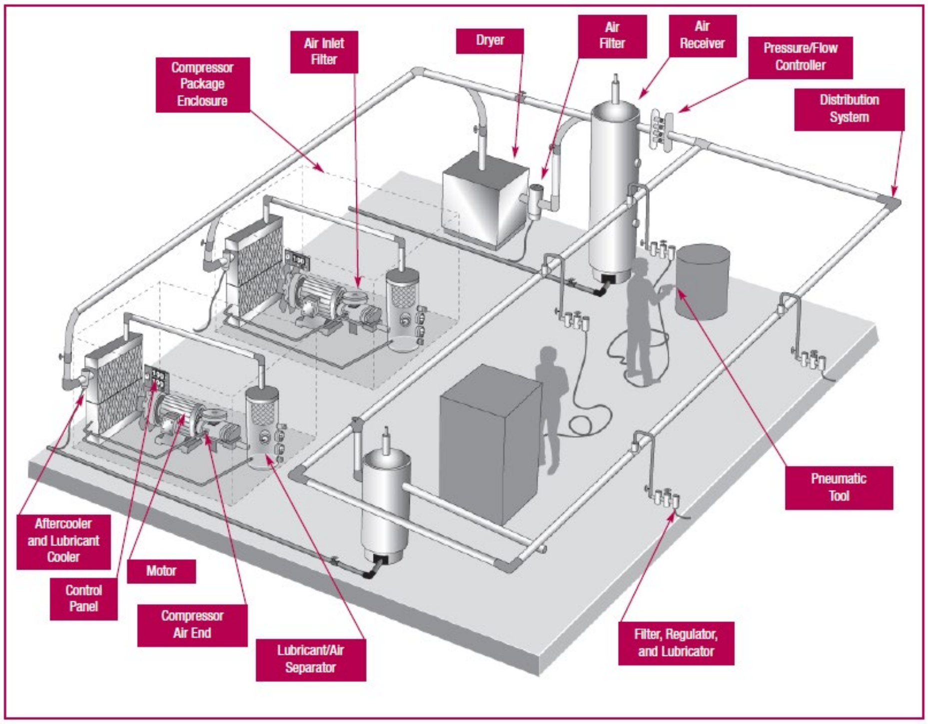
G. **Interconnection Piping:** Interconnection piping is considered to be the piping between compressor discharge outlets, conditioning equipment such as dryers and aftercoolers, and often the primary storage receiver prior to delivery to the main header. Interconnection piping often connects multiple compressors, as well.

H. **Main Header Piping:** Main header piping is the piping that delivers air from the interconnection piping to any distribution piping or sub-headers. This piping often begins at the outlet of a storage receiver or flow controller and terminates at distribution piping out to different areas of a facility. In some cases, there may not be main header piping if the distribution piping is simple enough to contain only a single diameter distribution loop or loops.

I. **Distribution Piping:** Distribution piping includes all piping after the main header and transports air to service lines.

J. **Service Line Piping:** Service lines, often called drops, are typically the smallest diameter piping that delivers air from distribution piping to individual or groups of end-uses. Any tubing such as flexible hoses or plastic tubing within end-uses is not considered service line piping and is not covered by the compressed air pipe sizing or leak testing requirements.

Figure 10-40: Typical Compressed Air System Components



Source: Improving Compressed Air System Performance: A Sourcebook for Industry, USDOE 2003

10.8.2 Mandatory Measures

§120.6(e)

There are six main mandatory requirements in this section:

a. Trim compressor and storage - §120.6(e)1,
b. Controls - §120.6(e)2,
c. Monitoring - §120.6(e)3,
d. Leak testing of compressed air piping - §120.6(e)4,
e. Pipe sizing - §120.6(e)5, and
f. Compressed air system acceptance - §120.6(e)6.

10.8.2.1 Trim Compressor and Storage

§120.6(e)1

This requirement targets the performance of a compressed air system across the full range of the system.

There are two paths to comply with this requirement:

1. Using a variable-speed drive (VSD) controlled compressor(s) as the trim compressor (§120.6(e)1A):

- The VSD trim compressor(s) must have a capacity (acfm) of at least 1.25 times the largest net capacity increment (see Example 10-54).
- Primary storage of at least one gallon per acfm (1 gal/acfm) of the largest trim compressor.

2. Using a compressor or set of compressors as the trim compressor (§120.6(e)1B) without requiring a VSD-controlled compressor:

   - The trim compressor(s) must have a total effective trim capacity no less than the largest net capacity increment.
   - Primary storage of at least two gallons per acfm (2 gal/acfm) of the largest trim compressor.
   - Effective trim capacity is the range of compressed air flow rates where the specific power (W/acfm) is no greater than 115% of the minimum specific power (Figure 10-42).

Both paths aim to reduce the amount of cycling of fixed-speed compressors by using a better-suited compressor that operates well in part-load.

A. Compliance Option 1: VSD-controlled Trim Compressor

§120.6(e)1A

Many base-load compressors are designed to provide peak efficiency near the rated capacity with a significant drop off in efficiency at lower flow rates (in acfm). Compressed air systems often avoid the losses in efficiency associated with part-load compressed air flows by staging multiple compressors so that in most cases base compressors operate near full load. A trim compressor is designed to have close to peak efficiency over a broad range of compressed air flow rates. To make sure the compressed air system is operating efficiently over the entire range, it is important to have a trim compressor sized to handle the gaps between base compressors. The minimum size of the trim compressor(s) is determined calculating the *Largest Net Capacity Increment* - the biggest step increase between combinations of base compressors.

With equally sized compressors, this is fairly intuitive: in a system with a two-100 hp (434 acfm) rotary screw compressor system, the largest step increase would be the size of one of the compressors (434 acfm). For systems with uneven compressor sizes, it requires going through the following steps:

1. Determine all combinations of base compressors (including all compressors off).
2. Order these combinations in increasing capacity.
3. Calculate the difference between every adjacent combination.
4. Choose the largest difference.

This largest difference is what must be covered by the trim compressor(s) to avoid a control gap.

Once the *largest net capacity increment* is calculated, this value can be used to satisfy the first compliance option. Option 1 mandates that the rated capacity of the VSD compressor(s) be at least 1.25 times the largest net increment.

For Compliance Option 1, the system must include primary storage that has a minimum capacity of 1 gallon for every acfm of capacity of the largest trim compressor.

Example 10-61

Question

Given a system with three base compressors with capacities of 200 acfm (Compressor A), 400 acfm (Compressor B), and 1,000 acfm (Compressor C), what is the *Largest Net Capacity Increment?*

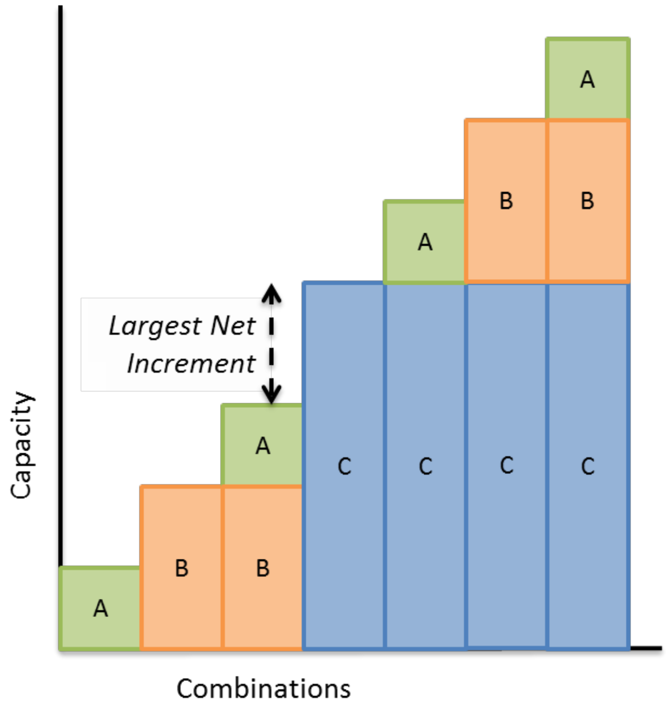
Answer

As shown in the image below, there are eight possible stages of capacity ranging from 0 acfm with no compressors to 1,600 acfm with all three compressors operating. The largest net increment is between Stage 4 with Compressors A and B operating (200+400=600 acfm) to stage 5 with compressor C operating (1,000 acfm)

Combinations of Base Compressors

Base Compressors	
A	200
B	400
C	1000

Capacity	Combination
0	None
200	A
400	B
600	A + B
1000	C
1200	A + C
1400	B + C
1600	A + B + C



For this system the *Largest Net Capacity Increment* is 1,000 acfm-600 acfm = 400 acfm

Example 10-62

Question

Using the system from the previous example, what is the minimum rated capacity of VSD compressor(s) that are needed to comply with Option 1*?*

Answer

As previously shown, the *Largest Net Capacity Increment* is 1,000 acfm-600 acfm = 400 acfm. The minimum rated capacity for VSD compressor(s) is 400 acfm X 1.25 = 500 acfm.

Example 10-63

Question

What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 1?

Answer

Assuming there is a VSD compressor with a rated capacity of 500 acfm, per §120.6(e)1A, it must have 1 gallon of storage per acfm of rated capacity or 500*1 = 500 gallons of storage.

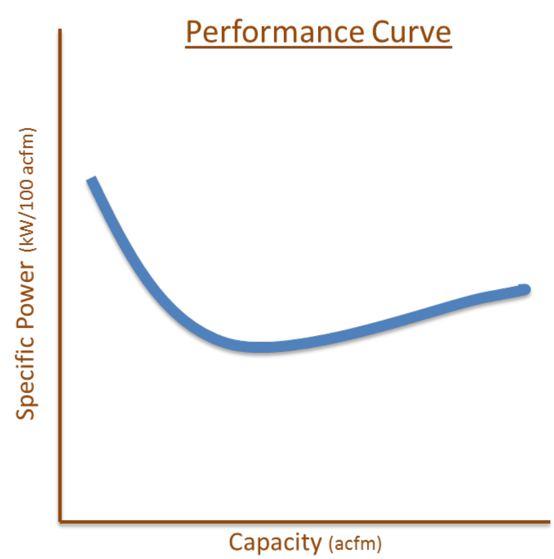
B. Compliance Option 2: Other Compressors as Trim Compressor

§120.6(e)1B

The second compliance option offers more flexibility but requires looking at both the largest net capacity increment of the system, as well as the effective trim capacity of the trim compressor(s).

The effective trim capacity is the range across which a trim compressor has adequate part-load performance. Performance is measured in power input over air volume output or specific power (kw/100 acfm). Many VSD compressors come with a compressor performance graph in a CAGI data sheet that looks similar to the graph in Figure 10-41.

Figure 10-41: Example Compressor Power vs. Capacity Curve

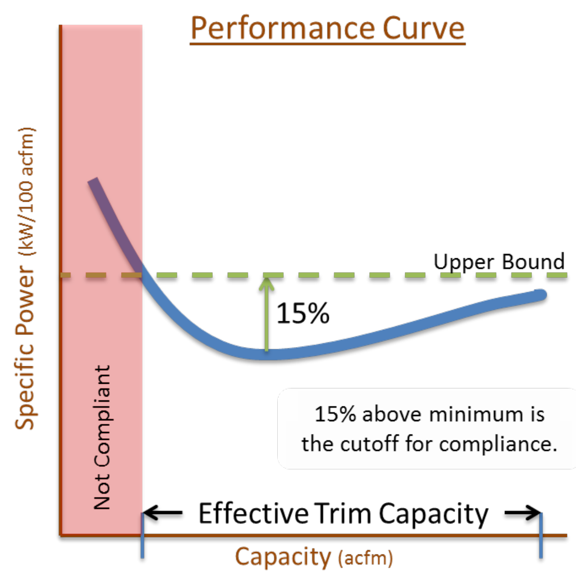


The capacity of the compressor is along the x-axis, while the power is on the y-axis. The curve in Figure 10-41 is a typical shape of a performance curve for a VSD compressor. The lower the specific power, the more energy-efficient the compressor is at that condition.

The effective trim capacity uses the minimum of the compressor power vs. capacity curve to determine the range of adequate part-load performance. This can be done in the following steps and is illustrated in the graph below.

1. Find the minimum specific power across the range.
2. Find the upper bound by calculating 1.15 times the minimum specific power.
3. Determine the endpoints of the capacity (acfm) where the specific power is less than or equal to the upper bound.
4. The capacity difference in units of acfm between these two endpoints is the effective trim capacity.

Figure 10-42: Determination of Effective Trim Capacity from a Compressor Curve



This definition of effective trim capacity, along with the largest net capacity increment of the system, is used to size the trim compressor appropriately in the next section.

For Compliance Option 2, the system must include primary storage that has a minimum capacity of 2 gallons for every acfm of capacity of the largest trim compressor.

Example 10-64

Question

Continuing with the system from the previous examples, what is the required minimum effective trim capacity of the trim compressor(s) to comply with Option 2*?*

Answer

As previously shown, the largest net capacity increment is (1,000 acfm) – (600 acfm) = 400 acfm. Per §120.6(e)1 the minimum effective trim capacity is equal to the largest Net Capacity Increment or 400 acfm.

Example 10-64

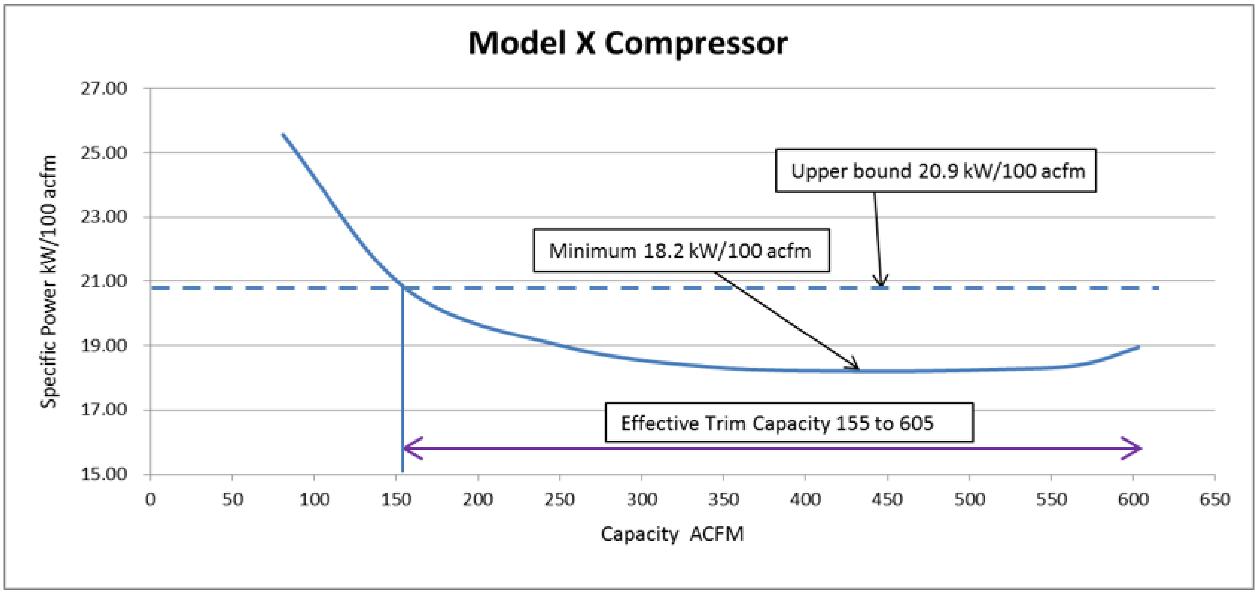
Question

A manufacturer provided the following data for its compressor; would this provide the minimum effective trim capacity for this system to comply with Option 2?

Input Power (kW)	Capacity (acfm)[a,d]	Specific Power (kW/100 acfm)[d]
20.7	81.0	25.56
32.4	156.0	20.77
47.5	250.0	19.00
62.7	342.0	18.33
79.0	434.0	18.20
94.2	516.0	18.26
104.3	567.0	18.40
114.2	603.0	18.94

Answer

From the manufacturer's data, the minimum specific power is 18.2 kW/100 acfm. The upper limit would be 18.2 * 1.15 = 20.9 kW/100 acfm. Interpolating from the manufacturer's data, this appears to go from 155 acfm to 605 acfm for an effective trim capacity of 605-155= 450 acfm. This is larger than the largest net capacity increment of 400 acfm, so this compressor would comply as a trim compressor for this system*.*



Example 10-65

Question

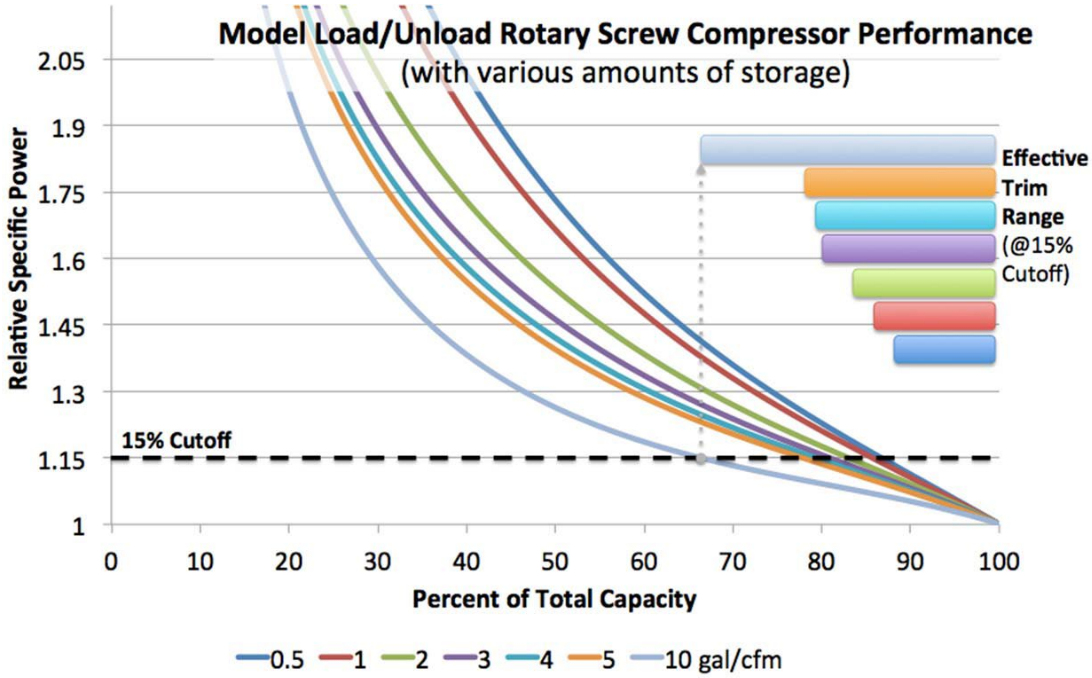
What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2?

Answer

This compressor has a rated capacity of 603 acfm. Per §120.6(e)1B, it must have 2 gallons of storage per acfm of rated capacity or 603*2 = 1,206 gallons of storage.

The last example used a VSD compressor, but other technologies can be used for compliance option 2 such as a compressor with unloaders and sufficient compressed air storage to achieve relatively high part-load efficiencies over a broad range of compressed airflow rates. Generally, higher levels of storage improve part-load performance. The following data, in Figure 10-43 and for this example, were generated from theoretical curves used in AirMaster+, a tool created by the U.S. Department of Energy.

Figure 10-43: Normalized Efficiency Curves for a Screw Compressor with Load/Unload Controls for Various Amounts of Storage



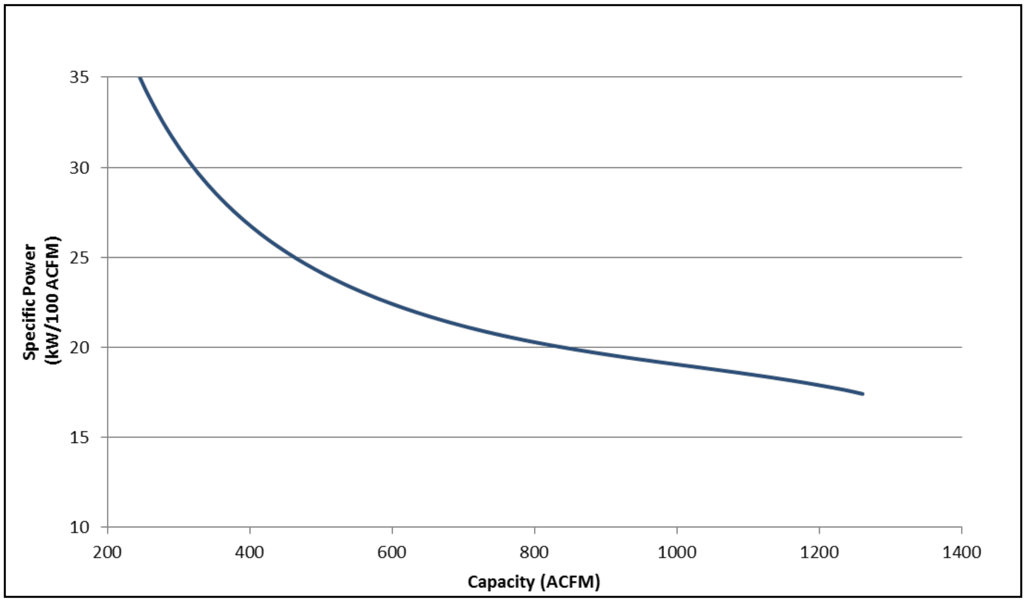
Source: Derived from Fact Sheet 6 – Compressed Air Storage, Improving Compressed Air Storage: A Sourcebook for Industry, U.S. Department of Energy, 2003

The next example examines a 250-hp load-unload, single-stage, rotary-screw compressor coupled with 10 gallons/cfm of storage. This combination of compressor and storage was chosen to meet the part-load performance mandated by code.

Example 10-66

Question

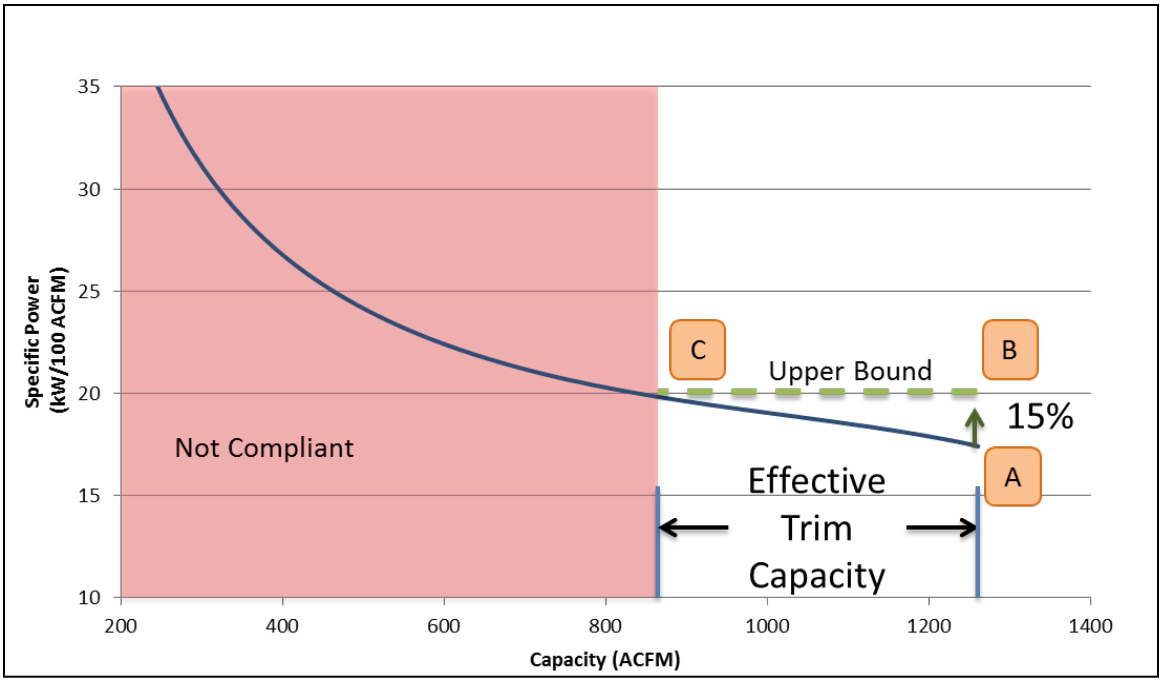
Part-load data were approximated below for a 250-hp load-unload, single-stage, rotary-screw compressor (with a capacity of 1,261 acfm) coupled with 10 gallons/cfm of storage. Would this provide the minimum effective trim capacity for this system to comply with Option 2 using the previous examples?



Answer

Using the previous examples, a compressor with an effective trim capacity of at least 400 acfm is necessary.

Looking at the graph, the minimum specific power (labeled as A below) occurs at full load - a capacity of 1,261 acfm, with a specific power of 17.4 kW/100 acfm. Using this minimum specific power, the upper bound is 17.4 * 1.15 = 20.01 kW/100acfm or 15% higher than the minimum specific power. This puts the ends of the effective trim capacity at 1261 acfm (labeled as B) and 845 acfm (labeled as C), resulting in an effective trim capacity of 1261 – 845 = 416 acfm. This is larger than the largest net capacity increment of 400 acfm, so this compressor would comply as a trim compressor for this system. The shaded area labeled "not compliant" is the portion of the compressor capacity that does not contribute to the total system effective trim capacity.



Example 10-67

Question

What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2?

Answer

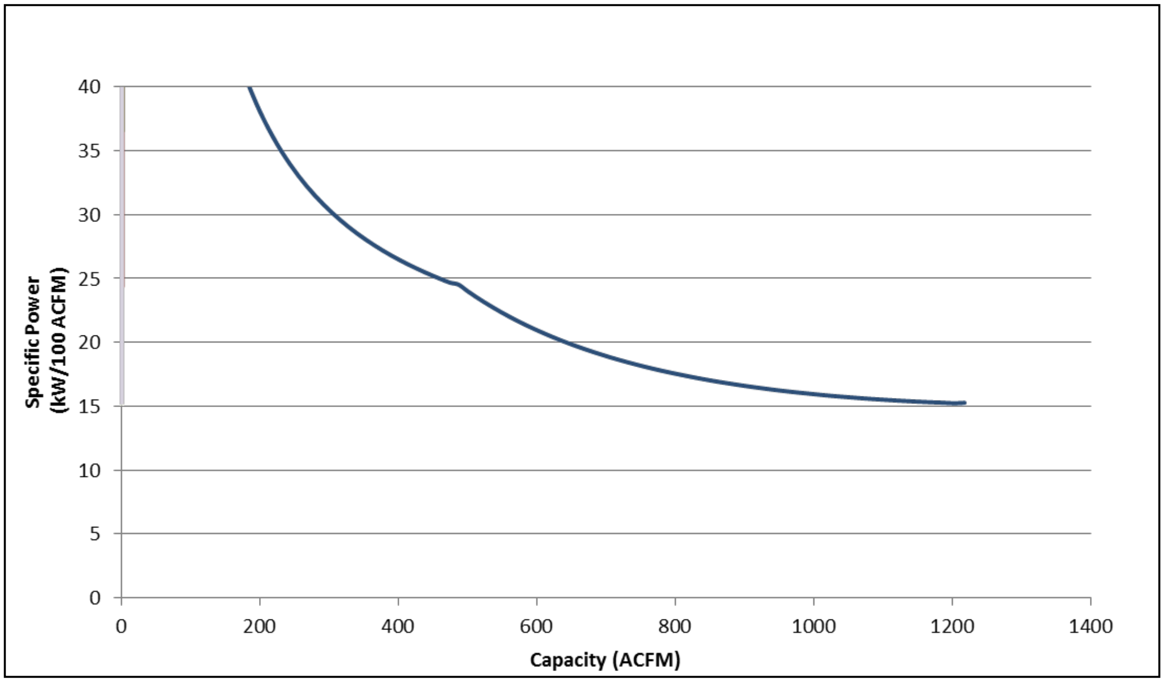
This compressor has a rated capacity of 1,261 acfm, and per §120.6(e)1B it must have 2 gallons of storage per acfm of rated capacity or 1261 * 2 = 2,522 gallons of storage.

However, a minimum of 10 gallons of storage per acfm was needed for the screw compressor with load/unload controls to have a large enough effective trim capacity. The minimum required primary storage to meet the effective trim capacity and storage requirements in §120.6(e)1B is 10 gal per acfm of rated trim compressor capacity; thus, the minimum primary storage capacity required is 1,261 * 10 = 12,610 gallons.

Example 10-68

Question

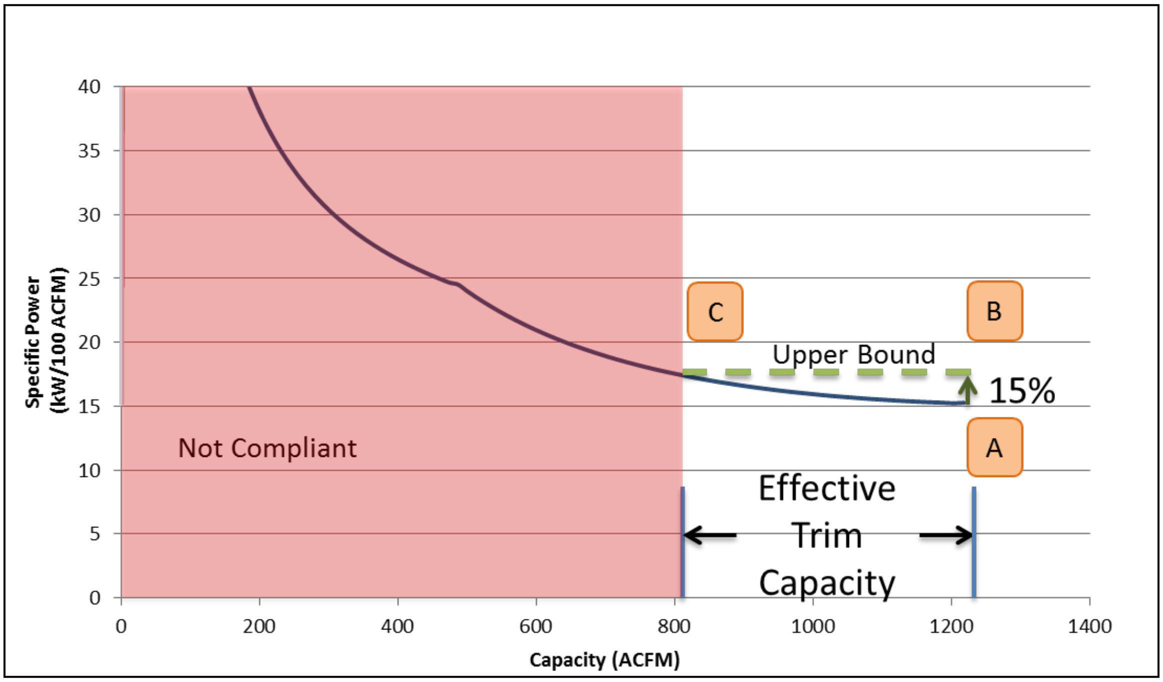
Part-load data were approximated below for a 250-hp variable-capacity compressor. Would this provide the minimum effective trim capacity for this system to comply with Option 2?



Answer

Using the previous examples, a compressor with an effective trim capacity of at least 400 acfm is necessary.

Looking at the graph, the minimum specific power (labeled as A below) occurs at full load - a capacity of 1,218 acfm, with a specific power of 15.3 kW/100 acfm. Using this minimum specific power, the upper bound is 15.3 * 1.15 = 17.56 kW/100 acfm or 15% higher than the minimum specific power. This puts the ends of the effective trim capacity at 1,218 acfm (labeled as B) and 804 acfm (labeled as C), resulting in an effective trim capacity of 1218 – 804 = 414 acfm. This is larger than the largest net capacity increment of 400 acfm so this compressor would comply as a trim compressor for this system.



Example 10-69

Question

What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2*?*

Answer

This compressor has a rated capacity of 1,218 acfm, and per §120.6(e)1B it must have 2 gallons of storage per acfm of rated capacity or 1,218 * 2 = 2,236 gallons of storage.

10.8.2.2 **Controls**

§120.6(e)2

This section applies to compressed air systems with more than one on-line compressor and a combined power of ≥100 hp. This section requires an automated control system that will optimally stage the compressors to minimize energy for the given load. With new systems, this ideally means that at any given load, the only compressors running at part-load are the trim compressors. Because not all systems are required to upgrade the trim compressor, the installed controls must stage the compressors in the most efficient manner.

This requirement also mandates the measurement of air demand. The control system must be able to measure or calculate the current system demand (in terms of actual cubic feet per minute of airflow). There are two ways to accomplish this, including, but not limited, to the following sensors:

1. A flow meter
2. A combination of pressure transducers and power meters

10.8.2.3 **Monitoring**

§120.6(e)3

This measure supports the ongoing optimization and tuning that is necessary to maintain compressed air system function and efficiency. This is done through specifying monitoring system minimum requirements for the compressed air system. Monitoring of compressed air pressure, input electrical power, and airflow enables identification of any poorly functioning plants, mechanical degradation, or increases in leak loads. Identifying these issues allows for informed maintenance and repair to systems that have unacceptable levels of waste, malfunctions, and inefficiencies. Monitoring of compressed air should be integrated into plant management protocols and facility operations as it can not only be a source for sustaining optimal energy efficiency but also a metric for factory health in an industrial setting. Monitoring of compressed air loads and efficiency is necessary for sustained system performance and energy benefits from the other requirements in §120.6(e).

Any new compressed air plant with combined nominal capacity equal to or greater than 100 hp nominal and any existing plant expanded or altered such that the combined capacity is equal to or greater than 100 hp must have a monitoring system with the following:

1. Measurement of system pressure.
2. Measurement of amps or power of each compressor.
3. Measurement or determination of total flow from the compressed air plant in cfm.
4. Data logging of pressure, power in kW, airflow in cfm, and compressed air specific efficiency in kW/100 cfm at intervals of 5 minutes or less.
5. Maintained data storage of at least the most recent 24 months.
6. Visual trending display of each recorded point, load, and specific energy.

Note that §120.6(e)3B allows for measurement of compressor input power in either amps or direct real power measurement in kW. Amps is allowable to accommodate the common practice of measuring amps and combining with voltage and power factor to estimate input power.

Note that §120.6(e)3C allows for measurement of compressed airflow output through either direct measurement of airflow or through calculation of airflow from performance data. These alternatives accommodate the two primary means of measuring airflow in the compressed air market.

Data storage and display can be accomplished at any potential user interface, from onboard packaged unit displays to integration into plant SCADA systems. Where possible, alarms for leak load limits, specific efficiency limits, and any other desired metrics should be programmed.

Example 10-70

Question

What data acquisition would be required to meet §120.6(e)3 part C, *Measurement or determination of total airflow from compressors in cfm*?

Answer

Part C specifies that two options for monitoring compressed air flow (cfm), either directly or indirectly a maximum of 5 minute intervals. Direct measurements will typically take the form of a probe or inline air flow meter. Indirect calculations would require the use of measurement of true power (kW) and estimating the airflow using compressor performance data. Performance data sheets can be provided by the air compressor manufacturer and/or national industry associations. This performance data is typically provided in the form of tables and/or performance curves. For many air compressors specific efficiency (kW/100 cfm) is a standard unit. The airflow can be indirectly measured by dividing the measured power by the specific efficiency.

Example 10-71

Question

How can the data gathered from equipment required by §120.6(e)3 be used for compressed air energy management?

Answer

Two primary energy benefits of the monitoring requirements come from maintenance of system efficiency and management of leak loads:

1. Compressed air system energy performance is typically quantified by specific power in kW/100 cfm. By monitoring specific power of a compressed air system, efficiency can be continuously managed and optimized over time. Facility staff should use regularly observe specific power monitoring to identify if and when the system begins to operate poorly. Staff should first identify what their compressor or compressed air specific power is after initial commissioning or optimization efforts. This serves as the baseline. If the specific power increases over time, facility staff should investigate or engage with their compressed air service providers to identify the source of performance degradation. This performance degradation will likely take the form of discrete, obvious spikes in specific power due to acute malfunctions or gradual increases over time. These increases in specific power affect the energy used for every cfm at all hours. Therefore, correction of any root causes or recommissioning will save energy for the entire compressed air system under all loads and hours.

2. Compressed air leak loads typically grow over time in most facilities due to unavoidable wear and tear. These leak loads are often 20-40% of total usage, resulting is large excessive, unproductive energy use and reliability issues at compressed air tools and end-uses. Monitoring of airflow in cfm can be used to identify when leak loads have grown to a level that warrants corrective action. Good practice is to target leak loads of about 10% with regular leak repair and management processes.

The monitoring system will allow facilities to observe loads in cfm for their plant. If the cfm monitoring shows that loads are growing over time without any corresponding production or operational changes, leak loads are likely growing. This leak load, energy use, and cost can be quantified by observing the cfm growth. This provides facility staff operational and financial justification for correcting leaks as well as showing the returns for doing so. Another useful approach for determining leak loads is to observe cfm trends during after-hours, breaks, or weekends with the compressors still on. This can very clearly show leak loads since most or all the output will likely be going to leaks if there are no tools or machines in use.

The monitoring system may be configured to flag or send alerts to facility staff when issues such as these are automatically identified by the monitoring system. This is optional and dependent of the monitoring system capabilities but can help streamline the process for many facilities.

10.8.2.4 **Leak Testing**

§120.6(e)4

This requirement targets the quality installation of new compressed air piping in both new construction and additions and alterations of existing piping. Piping greater than 50 adjoining feet in length shall be pressure tested to ensure minimal leakage rates after installation. The piping shall be pressurized to the system design pressure and help for at least 30 minutes without losing pressurization as indicated by test gauges measuring directly at the tested length of piping.

The pressure test should use dial pressure gauges conforming to the California Plumbing Code sections 318.3, 318.4, and 318.5. In the 2019 California Plumbing Code, these specify the following:

- Required pressure tests exceeding 10 psi (69 kPa) but less than or equal to 100 psi (689 kPa) shall be performed with gauges of 1 psi (7 kPa) incrementation or less.
- Required pressure tests exceeding 100 psi (689 kPa) shall be performed with gauges incremented for 2 percent or less of the required test pressure.
- Test gauges shall have a pressure range not exceeding twice the test pressure applied.

Piping less than or equal to 50 feet in adjoining length and connections shall be pressurized and manually inspected with a leak-detecting fluid.

In either case, if the piping fails to maintain pressure or leaks are detected, repairs or corrections must be made to the piping to eliminate the leak sources prior to re-testing.

The purpose of this requirement is to ensure quality installation of new piping. In many cases, it can be extremely difficult and disruptive to repair leaks in hard-to-reach, mission-critical piping once a system is commissioned and operational. Leak testing is necessary to ensure these issues are avoided at construction and are often standard or best practices by installing contractors.

10.8.2.5 **Pipe Sizing**

§120.6(e)5

This requirement targets the performance of a compressed air systems to minimize frictional losses.

For service line piping a minimum pipe diameter of ¾ inch is required. Flexible hoses and tubing at the end-uses are not covered by this requirement.

For compressor room interconnection, main header piping, and distribution piping there are two paths for compliance:

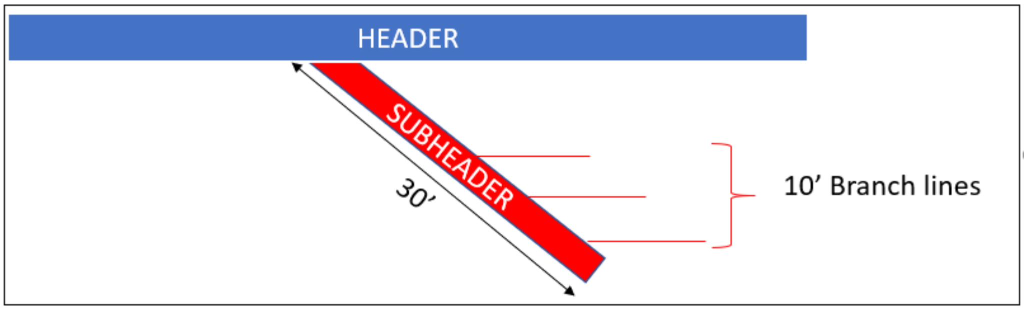
1. Piping section average velocity:
    - Interconnection and main header piping shall be sized so that at coincident peak flow conditions, the average velocity in the segment of pipe is no greater than 20 ft/sec.
    - Distribution piping shall be sized so that at coincident peak flow conditions, the average velocity in the segment of pipe is no greater than 30 ft/sec.
2. Piping total pressure drop:
    - Frictional pressure loss at coincident peak loads are less than 5 percent of operating pressure between the compressor and end-use or end-use regulator.

For the piping total pressure drop pathway, it should be noted that the pressure drop is based on piping frictional pressure losses and does not include pressure drops across components such as dryers, flow controllers, regulators, and other non-piping components.

Example 10-72

Question

An existing compressed air has installed a new 30-foot subheader with three 10-foot branch lines, what must be done to ensure this additional compressed air piping will comply?



Answer

This system is installing a total of 60 feet of adjoining compressed air system piping. To comply with §120.6(e)4, the section of piping must be isolated and undergo pressure testing for a minimum of 30 minutes with no perceptible drop in pressure. To comply with §120.6(e)5, the service line piping must have a minimum inner diameter of ¾ inch and must comply with either §120.6(e)5B OR §120.6(e)5C.

§120.6(e)5B requires a calculation of pipe size based on a targeted maximum pipe velocity. Inner diameter can be estimated through the following equation

$$d = \sqrt{\frac{576}{\pi}\frac{Q}{v}}$$

Where:

v = velocity of air in feet per **minute**

d = inside diameter of pipe in inches

Q = Maximum expected flowrate through pipe in cubic feet per minute

For the section of piping above, to minimize frictional losses by sizing the pipe for a maximum of 30 ft/second (1800 feet/minute), the resultant diameter would be 1.01 inches. Rounding to the most appropriate diameter would be 1 inch (inner diameter) pipe.

§120.6(e)5C would require the calculation of the total piping pressure drop. To satisfy this requirement the piping frictional pressure loss would need to be lower than 5 percent of the operating pressure at coincident peak load. This can be in the form of compressed air modeling software or hand calculations. Hand calculations typically reference available reference tables from handbooks and manufacturers.

Examining the section of pipe added above, the pressure loss over the section of pipe can be estimated using reference tables that will typically provide pressure loss (psi) per 100 ft of pipe. Assuming the added section is the section of pipe furthest from the compressor, we can estimate the pressure loss introduced by the added pipe.

Assuming:

Line Pressure = 100 PSIG

Air Flow = 10 CFM

Pipe Diameter = 1/2 inch

Online reference tables yield a pressure loss of 0.4 psi per 100 foot of schedule 40 steel pipe. As all branch lines are equivalent in length and further assuming all have an equivalent diameter (and area), then the length of pipe the pressure drop will need to be calculated for is 40 feet (30 feet + 10 feet). This would yield the following pressure loss:

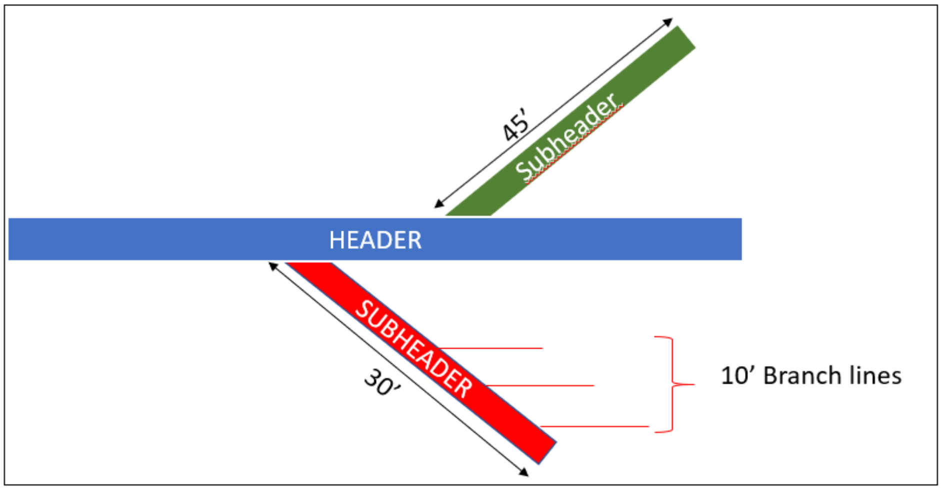
$$p = \frac{0.4}{100} * 40$$
$$p = 0.16$$

The resultant pressure loss of the section of pipe added would be 0.16 psi. Again, assuming this section of the pipe is the furthest from the compressor, a similar calculation would need to be performed across the total length of existing pipe leading to the end of the 10 foot branch line. To meet the requirements of §120.6(e)5C the total pressure loss calculated in this fashion should not exceed 5 percent of the operating pressure. E.g., for a given operating pressure of 115 psig, the total frictional pressure loss calculated would need to be less than 5.75 psig.

Example 10-73

Question

Using the distribution system from the previous example, an additional 45-foot subheader in a separate location of the compressed air distribution network. What testing and pipe sizing requirements will apply?



Answer

The section of piping from the previous example must still comply with §120.6(e)4 and §120.6(e)5A and §120.6(e)5B or §120.6(e)5C.

For the situation above when installing a new 30 foot subheader and three 10 foot branch lines, the maximum velocity would be 30 feet/second. To determine the inside diameter of the pipe the only information that will need to be referenced is the pressure loss due to flow through pipes which

As the additional 45-foot subheader is a separate section of piping in the same network but adjoining to an existing header that will not be altered, only §120.6(e)4 will apply. Furthermore, pressurized leak testing is not required on this section of piping and connections may be tested with noncorrosive leak-detecting fluid or other leak detecting methods.

10.8.3 Compressed Air System Acceptance

§120.6(e)6

New systems and altered systems that are subject to the trim compressor requirements of §120.6(e)1, staging control requirements of §120.6(e)2, or monitoring requirements of §120.6(e)3 must be tested per NA7.13.

10.8.4 Prescriptive Measures

§140.9

There are no prescriptive measures for compressed air systems.

10.8.5 Additions and Alterations

There are six requirements in this section for compressed air systems additions and alterations:

a. Trim compressor and storage - §120.6(e)1,

b. Controls - §120.6(e)2,

c. Monitoring - §120.6(e)3,

d. Leak testing of compressed air piping - §120.6(e)4,

e. Pipe sizing - §120.6(e)5, and

f. Acceptance - §120.6(e)6.

These requirements apply to existing systems that are being altered and that have a total compressor capacity ≥ 25 hp. These requirements will be triggered by replacing a compressor, adding a compressor, or removing a compressor.

These requirements do not apply to:

- Repairing a compressor.
- Replacing a compressor drive motor.
- Adding compressed air controls.
- Adding air dryers.
- Adding oil separators.
- Adding compressed air storage capacity.
- Removing an air compressor without adding any air compressors.

For alterations or additions to an existing compressed air system, requirement §120.6(e)1 for trim compressor size and storage do not apply when the total combined added or replaced compressor horsepower is less than the average per-compressor horsepower of all compressors in the system, or when all added or replaced compressors are variable speed drive compressors and the compressed air system includes primary storage of at least one gallon per actual cubic feet per minute (acfm) of the largest trim compressor.

For alterations or additions to an existing compressed air system, requirement §120.6(e)2 for controls applies only when the compressed air system has three or more compressors and a combined horsepower rating of more than 100 horsepower.

For alterations or additions to an existing compressed air system, requirement §120.6(e)3 for monitoring applies only when the compressed air system has a combined horsepower rating of more than 100 horsepower. Monitoring equipment can be used to identify changes in system performance for the purpose of identifying inefficiencies such as air leaks.

For alterations or additions to an existing compressed air system, requirement §120.6(e)4 for leak testing of compressed air piping applies to added or altered piping with leak testing requirements based on the length of adjoining pipe added or altered.

For alterations or additions to an existing compressed air system, requirement §120.6(e)5 for pipe sizing only applies when the added or altered piping is greater than 50 adjoining feet in length. For service line piping a minimum pipe diameter of ¾ inch is required. Flexible hoses and tubing at the end-uses are not covered by this requirement. For compressor room interconnection, main header piping, and distribution piping there are two paths for compliance as described in 10.8.2.5.

For alterations or additions to an existing compressed air system, requirement §120.6(e)6 for compressed air system acceptance testing will apply based on which other compressed air system requirements are required. For example, if an addition or alteration to a compressed air system triggers the controls requirement in 120.6(e)3, then the acceptance requirements associated with controls are also required.

Example 10-74

Question

If a 50 hp compressor was added to a compressed air system with only one existing 100 hp compressor, would the requirements of §120.6(e) apply?

Answer

Each subsection of §120.6(e) would need to be evaluated to determine which requirements are applicable and which requirements are not.

Requirements for trim and compressor and storage are not applicable because 50 hp is Less than the average per-compressor horsepower of all compressors in the system. Requirements for controls in §120.6(e)2 are not applicable because the compressed air system has less than three compressors. Requirements for leak testing of compressed air piping in §120.6(e)4 and pipe sizing in §120.6(e)5 are not applicable because compressed air piping is not being added.

Requirements for monitoring in §120.6(e)3 are required because the system has a combined horsepower rating greater than 100 hp. Additionally, compressed air system acceptance requirements in §120.6(e)6 pertaining to the monitoring system will also be applicable.

10.9 Process Boilers

10.9.1 Overview

A *process boiler* is a type of boiler with a capacity (rated maximum input) of 300,000 Btu/h or more that serves a process. A *process* is an activity or treatment that is not related to the space conditioning, service water heating, or ventilating of a building as it relates to human occupancy.

10.9.2 Mandatory Measures

§120.6(d)

10.9.2.1 Combustion Air

§120.6(d)1

Combustion air positive shutoff shall be provided on all newly installed process boilers as follows:

- All process boilers with an input capacity of 2.5 MMBtu/h (2,500,000 Btu/h) and above, in which the boiler is designed to operate with a non-positive vent static pressure. This is sometimes referred to as *natural draft* or *atmospheric boilers*. Forced draft boilers, which rely on a fan to provide the appropriate amount of air into the combustion chamber, are exempt from this requirement.
- All process boilers where one stack serves two or more boilers with a combined input capacity per stack of 2.5 MMBtu/h (2,500,000 Btu/h). This requirement applies to natural draft and forced draft boilers.

Combustion air positive shutoff is a means of restricting air flow through a boiler combustion chamber during standby periods and is used to reduce standby heat loss. A flue damper and a vent damper are two examples of combustion air positive shutoff devices.

Installed dampers can be interlocked with the gas valve so that the damper closes and inhibits airflow through the heat transfer surfaces when the burner has cycled off, thus reducing standby losses. Natural draft boilers receive the most benefit from draft dampers because they have less resistance to airflow than forced draft boilers. Forced draft boilers rely on the driving force of the fan to push the combustion gases through an air path that has relatively higher resistance to flow than in a natural draft boiler. Positive shutoff on a forced draft boiler is most important on systems with a tall stack height or multiple boiler systems sharing a common stack.

10.9.2.2 Combustion Air Fans

§120.6(d)2

Combustion air fans with motors 10 horsepower or larger shall meet one of the following for newly installed boilers:

1. The fan motor shall be driven by a variable-speed drive, or
2. The fan motor shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume.

Electricity savings result from run time at part-load conditions. As the boiler firing rate decreases, the combustion air fan speed can be decreased.

10.9.2.3 **Excess Oxygen ≥ 5 MMBtu/h**

§120.6(d)3

Newly installed process boilers with an input capacity of 5 MMBtu/h (5,000,000 Btu/h) shall maintain excess (stack-gas) oxygen concentrations at less than or equal to 3.0 percent by volume on a dry basis over firing rates of 20 percent to 100 percent. Combustion air volume shall be controlled with respect to measured flue gas oxygen concentration. Use of a common gas and combustion air control linkage or jack shaft is prohibited.

One way to meet this requirement is with parallel position control. Boilers mix air with fuel (usually natural gas, although sometimes diesel or oil) to supply oxygen during combustion. Stoichiometric combustion is the ideal air/fuel ratio where the mixing proportion is correct, the fuel is completely burned, and the oxygen is entirely consumed. Boilers operate most efficiently when the combustion airflow rate is slightly higher than the stoichiometric air-fuel ratio. However, common practice almost always relies on excess air to ensure complete combustion, avoid unburned fuel and potential explosion, and prevent soot and smoke in the exhaust. Excess air has a penalty, which is increased stack heat loss and reduced combustion efficiency.

Parallel positioning controls optimize the combustion excess air to improve the combustion efficiency of the boiler. It includes individual servo motors allowing the fuel supply valve and the combustion air damper to operate independently of each other. This system relies on preset fuel mapping (i.e., a pre-programmed combustion curve) to establish proper air damper positions (as a function of the fuel valve position) throughout the full range of burner fire rate. Developing the combustion curve is a manual process, performed in the field with a flue-gas analyzer in the exhaust stack, determining the air damper positions as a function of the firing rate/fuel valve position. Depending on type of burner, a more consistent level of excess oxygen can be achieved with parallel position compared to single-point positioning control, since the combustion curve is developed at multiple points (firing rates), typically 10 to 25 points. Parallel positioning controls allow excess air to remain relatively low throughout the firing range of a burner. Maintaining low excess air levels at all firing rates provides significant fuel and cost savings while maintaining a safe margin of excess air to insure complete combustion.

10.9.3 Prescriptive Measures

There are no prescriptive measures for process boilers.

10.10 Elevators

10.10.1 Overview

Section 120.6(f) applies to all nonresidential new construction elevators, as well existing elevators undergoing major alterations involving mechanical equipment, lighting, and/or controls. The goal behind this measure is to save energy by reducing light power density of the elevator cab lighting and requiring a minimum wattage per cfm for ventilation fans in cabs without air conditioning. Both the lighting and ventilation fans are to be controlled in such a way to shut off when the elevator has been unoccupied for an extended period. Elevators in healthcare facilities have an exception to the requirements of this section.

10.10.2 Mandatory Measures

§120.6(f)

10.10.2.1 Elevator Lighting Power Density

§120.6(f)1

The lighting power density of an elevator cab shall not exceed 0.6 watts per square foot (W/ft^2). This power density is determined by taking the total wattage of the elevator lighting and dividing by the floor area of the elevator in square feet. Interior signal lighting and interior display lighting are not included in the total wattage of the elevator lighting.

Example 10-75

Question

An elevator with a length of 6 ft and a width of 8 ft has 9 light-emitting diode (LED) lamps at 3 watts each. Does this comply with §120.6(f).1?

Answer

Yes. (9 lamps) x (3 watts/lamp) = 27 watts. The square footage of the cab is (6 ft) x (8 ft) = 48 ft^2. The lighting power density is equal to 27 watts/48 ft^2 = 0.56 W/ft^2, which is less than 0.6 W/ft^2.

10.10.2.2 Elevator Ventilation CFM Fan Performance

§120.6(f)2

Ventilation fans for cabs without space conditioning shall not exceed 0.33 watts per cubic feet per minute of airflow (W/cfm) at maximum speed. Elevator cabs with space conditioning are excluded from this measure.

10.10.2.3 Elevator Lighting and Fan Shutoff Control

§120.6(f)3

When the elevator cab is stopped and unoccupied with doors closed for more than 15 minutes, the cab interior lighting and ventilation fans shall automatically switch off until elevator cab operation resumes. This can be accomplished with an occupancy sensor or more elaborate built in elevator controls.

10.10.3 Prescriptive Measures

There are no prescriptive measures for elevators.

10.10.4 Additions and Alterations

- **An** elevator installation is considered an addition when the location of the installation did not previously contain an elevator.
- **An** alteration **is a change to an existing elevator system that is not an addition or repair. An alteration could include installing new controls or a new lighting system.**
- A repair is the reconstruction or renewal of any part of an existing elevator system for its maintenance, for example, the replacement of lights or cosmetic features.

Any addition or altered space must meet all applicable mandatory requirements. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered an alteration.

10.11 Escalators and Moving Walkways

10.11.1 Overview

Section 120.6(g) applies to nonresidential new construction escalators and moving walkways in airports, hotels, and transportation function areas, as well as existing escalators and moving walkways undergoing major alterations involving mechanical equipment or controls in the same locations. The goal behind this measure is to save energy by reducing the full-speed run time of the escalator by slowing it down when unoccupied.

10.11.2 Mandatory Measures

§120.6(g)

10.11.2.1 Escalator and Moving Walkway Speed Control

§120.6(g)1

Escalators and moving walkways in airports, hotels, and transportation function areas shall automatically slow to the minimum permitted speed in accordance with ASME A17.1/CSA B44 when not conveying passengers.

The ASME A17.1/CSA B44 2013 requirements for intermittent speed control on escalators and moving walkways are summarized below. These requirements are necessary to ensure maximum passenger safety when speeding up or slowing down escalators and moving walkways. To comply with the Energy Codes, the escalator or moving walkway must also comply with ASME A17.1/CSA B44 2013. Additional safety requirements may exist in Title 8.

Variation of the escalator and moving walkway speed after start-up shall be permitted provided the escalator and moving walkway installation conforms to all of the following:

1. The acceleration and deceleration rates shall not exceed 0.3 m/s^2 (1.0 ft/s^2).
2. The rated speed is not exceeded.
3. The minimum speed shall be not less than 0.05 m/s (10 ft/min).
4. The speed shall not automatically vary during inspection operation.
5. Passenger detection means shall be provided at both landings of the escalator such that:
    a. Detection of any approaching passenger shall cause the escalator or moving walkway to accelerate to, or maintain the full speed conforming to (1) through (4) above.
    b. Detection of any approaching passenger shall occur sufficiently in advance of boarding to cause the escalator or moving walkway to attain full operating speed before a passenger walking at normal speed [1.35 m/s (270 fpm)] reaches the comb plate.
    c. Passenger detection means shall remain active at the egress landing to detect any passenger approaching against the direction of escalator or moving walkway travel and shall cause the escalator or moving walkway to accelerate to full rated speed and sound the alarm at the approaching landing before the passenger reaches the comb plate.
6. Automatic deceleration shall not occur before a specific period of time has elapsed since the last passenger detection that is greater than three times the amount of time necessary to transfer a passenger between landings.
7. Means shall be provided to detect failure of the passenger detection means and shall cause the escalator or moving walkway to operate at full rated speed only.

Figure 10-44: Example of Pedestrian Detection Method Using Motion Sensors

Source: wwwtelcosensors.com/solutions/industries/elevators

From 6.1.4.1 of ASME A17.1-2013/CSA B44-13, the maximum speed of escalators cannot be more than 0.5 m/s (100 ft/min), measured along the centerline of the steps in the direction of travel.

From 6.2.4.1 of ASME A17.1-2013/CSA B44-13 the maximum speed of a moving walkway depends on the maximum slope at any point on the treadway as listed below:

1. Max slope of 0-8 degrees: 0.9 m/s (180 ft/min)
2. Max slope above 8 & less than 12 degrees: 0.7 m/s (140 ft/min)

Escalator speed control is required only in airports, hotels, and transportation function areas. A transportation function area is defined in §100.1 of the Energy Code as the ticketing area, waiting area, baggage handling areas, concourse, in an airport terminal, bus or rail terminal or station, subway or transit station, or a marine terminal. The reason behind limiting the scope of this measure was to focus on escalators and moving walkways that experience pedestrian flow rates in waves and are more likely to operate 24 hours a day. An escalator in a busy shopping mall that operates only 12 hours a day may experience a constant pedestrian flow rate throughout the day and would rarely slow down and, therefore, save little energy. For these continuously busy applications during the operating hours of the escalator, the speed control would not be cost-effective.

10.11.3 Prescriptive Measures

There are no prescriptive measures for escalators or moving walkways.

10.11.4 Additions and Alterations

- An **escalator or moving walkway installation is considered an addition when the location of the installation did not previously contain an escalator.**
- An **alteration** is a change to an existing escalator or moving walkway system that is not an addition or repair. An alteration could include installing new controls or motor.
- A **repair** is the reconstruction or renewal of any part of an existing escalator or moving walkway system for maintenance. For example, a repair could include the replacement of a damaged step or handrail.

Any addition or altered space must meet all applicable mandatory requirements. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered to be an alteration.

10.12 Controlled Environment Horticulture

10.12.1 Overview

Section 120.6(h) sets efficiency standards for controlled environment horticulture (CEH) spaces. These standards are divided into indoor facilities which do not use sunlight and greenhouse CEH facilities. For indoor facilities, requirements exist for lighting technology and dehumidification. For greenhouses, there are requirements for lighting and building envelope materials. These requirements impact all newly constructed CEH spaces. These requirements will help reduce the energy usage of horticulture facilities that are becoming increasingly popular business operations across the state. These requirements not dependent on the type of crop is being grown in the facility.

10.12.2 Mandatory Measures

§120.6(h)

There are two main mandatory requirements in this section:

a. Indoor horticultural growing facilities - *§120.6(h)1 - 3*, and
b. Greenhouse facilities - *§120.6(h)4.*

10.12.2.1 Indoor growing dehumidification

§120.6(h)1

Section 120.6(h)1 sets efficiency standards for dehumidification equipment for indoor facilities. Compliance can be reached with one of the four following pathways.

- Dehumidifiers subject to federal appliance standards that comply with the federal performance and testing requirements; or
- Integrated HVAC system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or
- Chilled water system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or
- Solid or liquid desiccant dehumidification system for system designs that require dewpoint of 50°F or less.

Example 10-76

Question

How do I find a dehumidifier that meets the federal regulations?

Answer

The Department of Energy’s Compliance Certification Management System maintains a database of products that have been certified to meet the federal requirements.

10.12.2.2 Indoor growing horticultural lighting

§120.6(h)2

Section 120.6(h)2 requires indoor CEH growing spaces with more than 40 kilowatts (kW) of horticultural lighting load to have electric lighting systems used for plant growth and maintenance that meet all of the below requirements:

1. Luminaires with removable lamps shall contain lamps with a rated photosynthetic photon efficacy (PPE) of at least 1.9 micromoles per joule (μm/J). All other luminaires shall have a rated PPE of at least 1.9 μm/J for the wavelengths between 400 and 700 nm. Photosynthetic photon efficacy is photosynthetic photon flux for the wavelengths between 400 nm and 700 nm divided by input electric power in units of micromoles per second per watt, or micromoles per joule as defined by ANSI/ASABE S640.

   Note that some manufactures will also publish the total photon flux which includes the wavelengths outside of the 400 to 700 nm range. This higher photon flux value should not be used to calculate PPE as it includes wavelengths that are not photosynthetically active as defined by ANSI/ASABE S640.

2. Time-switch lighting controls shall be installed and comply with Section 110.9(b)1, the lighting control acceptance requirements of Section 130.4(a)4, and applicable sections of NA7.6.2.
3. Multilevel lighting controls shall be installed and comply with Section 130.1(b).

10.12.2.3 Indoor growing electrical power distribution

§120.6(h)3

Electrical power distribution systems servicing indoor CEH spaces must be designed so that a measurement device is capable of monitoring the electric energy usage of aggregate horticultural lighting load.

A 40 kW threshold equates to roughly 800-1,000 square feet of canopy for an indoor grower using 1,000 watt high pressure sodium lights every 20-25 square feet. For compliance with existing California Department of Food & Agriculture CalCannabis regulations, growers must submit canopy size calculations and a lighting diagram for indoor and mixed-light licensing types. The lighting diagram includes the maximum wattage for each light so through this diagram one can determine total horticulture lighting load.

Luminaires with a PPE of 1.9 micromoles per joule will largely be LED with a tuned spectrum for growing plants or double-ended high-pressure sodium (HPS) lamps . LEDs are becoming more popular in the market as growers become familiar with their impacts on plant quality and yield. A photosynthetic photon efficacy (PPE) of 1.9 micromoles per joule for lamps can be met by high efficiency double-ended high-pressure sodium (HPS) lamps. HPS technology has been in the horticulture market for considerable time and use of highly efficient options will allow growers to use familiar technology while still achieving energy savings.

Example 10-77

Question

How do I find the photosynthetic photon efficacy of a particular lighting fixture or lamp?

Answer

A variety of options exist to determine the PPE of a given product. The DesignLights Consortium (DLC) Qualified Products List notes the PPE level of over 415 products from popular lighting manufacturers. If your product is not found in this listing, your manufacturer's product specification may list PPE. Additionally, there are industry test procedures that can assist in the determination of a PPE level. IES LM-46-04: IESNA Approved Method for Photometric Testing of Indoor Luminaires Using High Intensity Discharge or Incandescent Filament Lamps is the most appropriate test standard for lamps and can be used to report PPE when certain data gaps are filled. The information needed to conduct the test procedure for PPE is found in existing IES standards, LM-51 and LM-79.

10.12.2.4 Conditioned greenhouse building envelope

§120.6(h)4

Section 120.6(h)4 provides separate building envelope requirements for conditioned greenhouses. Roof/ceiling and wall insulation must meet assembly requirements of Section 120.7. Buildings have different U-factor requirements for roof/ceiling and wall insulation depending on whether they are constructed with metal or wood products and their climate zones.

Non-opaque wall and non-opaque roof assemblies shall have greenhouse glazing with two or more glazing layers separated by air or gas fill.

Examples of non-opaque glazing products that meet these requirements include double pane glass, double and triple wall polycarbonate, and double film polyethylene.

10.12.2.5 Conditioned greenhouse space-conditioning systems

§120.6(h)5

Section 120.6(h)5 requires that space-conditioning systems used in conditioned greenhouses for plant production must meet requirements applicable to the systems

10.12.2.6 Greenhouse horticultural lighting

§120.6(h)6

Pertaining to Section 120.6(h)6, greenhouse growing spaces with more than 40 kW of horticultural lighting load shall have electric lighting systems used for plant growth and maintenance that meet all of the below requirements:

1. Luminaires with removable lamps shall contain lamps with a lamp photosynthetic photon efficacy (PPE) of at least 1.7 micromoles per joule (μm/J); all other luminaires shall have a luminaire photosynthetic photon efficacy of at least 1.7 μm/J.

2. Time-switch lighting controls shall be installed and comply with Section 110.9(b)1, Section 130.4(a)4, and applicable sections of NA 7.6.2.

3. Multilevel lighting controls shall be installed and comply with Section 130.1(b).

A lamp and luminaire PPE of 1.7 μm/J can be met by high efficiency double-ended high-pressure sodium (HPS) and ceramic metal halide (CMH) lamps. HPS and CMH technology have been in the horticulture market for considerable time and use of highly efficient options will allow growers to use familiar technology while still achieving energy savings. LED technology is also an option for attaining a luminaire PPE of 1.7 μm/J.

Example 10-78

Question

How do these Title 24, Part 6 requirements interact with any CalCannabis requirements?

Answer

Title 24, Part 6 requirements for CEH greenhouses and indoor growing spaces apply to all building spaces that "are dedicated to plant production by manipulating indoor environmental conditions, such as through electric lighting, mechanical heating, mechanical cooling, or dehumidification." The Title 24, part 6 requirements apply regardless of the type of crop grown in these spaces. Title 24, part 6 defines a CEH indoor growing space as having a skylight area to roof area ratio less than 50 percent. A CEH greenhouse has a skylight area to roof area ratio of 50 percent or greater. Thus, the Title 24 definitions of greenhouse and indoor growing space are solely determined by the fraction of roof area that has glazing and is not affected by how much electric lighting is used in the space.

CalCannabis (operated by the Department of Cannabis Control) grants licenses for cannabis growing. Different types of licenses are based on factors such as lighting density and light deprivation. As of 2021, CalCannabis defines Indoor Cultivation as "Cultivation of cannabis within a permanent structure using artificial light exclusively, or within any type of structure using artificial light at a rate above 25 watts per square foot." Therefore, a CalCannabis indoor cultivation license applies to indoor spaces with no skylights and any space, even greenhouses, with more than 25 Watts of electric lighting per square foot of growing area. A CalCannabis mixed light cultivation license makes use of some amount of sunlight and must have no more than 25 Watts of electric lighting power installed per square foot of growing area.

The CalCannabis definitions of "indoor growing" and "mixed light" for licensure are not equivalent to the "indoor growing" and "conditioned greenhouse" definitions used for obtaining building permits under Title 24, Part 6 and are not relevant to Title 24 compliance.

10.12.3 Prescriptive Measures

There are no prescriptive measures for controlled environmental horticulture.

10.12.4 Additions and Alterations

Section 120.6(h) applies to major retrofits of all CEH spaces. Alterations to indoor or greenhouse horticulture lighting systems that increase lighting wattage or that include adding, replacing, or altering 10 percent of more of the horticulture luminaires servicing an enclosed space must meet the applicable requirements of Section 120.6(h).

Greenhouses being converted into conditioned greenhouses or additions to conditioned greenhouses meet requirements of 120.6(h)4. A conditioned greenhouse is an enclosed space that is provided with wood heating, mechanical heating that has a capacity exceeding 10 Btu/hr-ft2 or mechanical cooling with capacity exceeding 5 Btu/hr-ft2. In conditioned greenhouses, space-conditioning systems used for plant production shall comply with all applicable Title 24, Part 6 requirements.

Example 10-79

Question

Alterations that change the occupancy group of a building do trigger the CEH requirements. Occupancy groups are defined in Chapter 3 of Title 24, Part 2. One common change of building type that would trigger the requirements is converting an indoor warehouse into a CEH grow facility of over 10 percent of the luminaires in my greenhouse or indoor CEH facility. Do I need to meet the lighting efficiency standards in 120.6(h)2 or 6?

Answer

Lamp replacements do not trigger the horticulture lighting efficacy alteration requirements. Only replacement of 10 percent or more of the horticulture luminaires serving an enclosed space trigger the lighting efficacy requirement. When replacing 10 percent or more of the luminaires in an enclosed space, only the replacement luminaires need to meet the applicable requirements.

Example 10-80

Question

If I replace the lamps of over 10 percent of the luminaires in my greenhouse or indoor CEH facility, do I need to meet the lighting efficiency standards in 120.6(h)2 or 6?

Answer

Lamp replacements do not trigger the horticulture lighting efficacy alteration requirements. Only replacement of 10 percent or more of the horticulture luminaires serving an enclosed space trigger the lighting efficacy requirement. When replacing 10 percent or more of the luminaires in an enclosed space, only the replacement luminaires need to meet the applicable requirements.

10.13 Steam Traps

10.13.1 Overview

§120.6(i) applies to new industrial facilities where the steam trap operating pressure is greater than 15 psig and the total combined connected boiler input rating is greater than 5 million Btu/hr. §120.6(i) also applies to new steam traps added to support new, non-replacement, process equipment in existing industrial facilities where the steam trap operating press is greater than 15 psig and the total combined connected boiler input rating is greater than 5 million Btu/hr. Existing steam traps that are being replaced due to failure are not required to meet §120.6(i). An exception is given to steam traps where steam is diverted to a steam system of lower pressure for use when the steam trap fails open, as might be found in a cascading process where steam is flashed to a lower pressure process. These traps would be exempted from the requirements of this section. However, the traps on the lowest pressure section which are discharging to the drain or condensate system are still covered.

10.13.2 Mandatory Measures

§120.6(i)

There are four main mandatory requirements in this section:

a. Central steam trap fault detection and diagnostic monitoring - §120.6(i)1,

b. Steam trap fault detection - §120.6(i)2,

c. Steam trap strainer installation - §120.6(i)3, and

d. Steam trap system acceptance - §120.6(i)4.

10.13.3 Central Steam Trap Fault Detection and Diagnostic Monitoring

§120.6(i)1

There are two requirements for steam trap monitoring systems:

1. Provide status updates of all fault detection sensors to the central monitoring station at least every 8 hours, and
2. Automatically display an alarm that identifies which steam trap has a fault.

10.13.4 Steam Trap Fault Detection

§120.6(i)2

This requirement indicates that steam traps must have automatic fault detection sensors that can communicate with the central steam trap monitoring system described in §120.6(i)1.

10.13.5 Steam Trap Strainer Installation

§120.6(i)3

This requirement identifies two options for meeting steam trap strainers:

- The strainer and blow-off valve must be integrated into the steam trap, or
- The steam trap must be installed within 3 feet downstream of the strainer and blow-off valve.

10.13.6 Steam Trap System Acceptance

§120.6(i)3

Before an occupancy permit is granted for compliance with §120.6(i) the equipment and systems should be certified as meeting the Acceptance Requirement for Code Compliance, as specified by NA7.19. A Certificate of Acceptance shall be submitted to the enforcement agency.

10.13.7 Prescriptive Measures

There are no prescriptive measures for steam traps.

10.13.8 Additions and Alterations

Section 120.6(i) applies to new steam traps added to support new, non-replacement, process equipment in existing industrial facilities where the steam trap operating press is greater than 15 psi and the total combined connected boiler input rating is greater than 5 million Btu/hr. If new steam lines including steam traps are added as part of an addition or alteration to an industrial facility, these steam traps are required to meet §120.6(i) as described above.

Example 10-81

A manufacturing facility has a 100 psig steam system served by three boilers, each rated at 3 million Btu/hr input rating and 2.5 million Btu/hr output rating. Two boilers are active, and one boiler is a back-up.

Question 1: What is the combined total rating of the system?

Answer: The combined input rating is 9 million Btu/hr; it includes all boilers physically connected to the steam piping system including back-ups. Since the input rating of this steam system is greater than 5 million Btu/hr, it is large enough for the steam trap FDD requirements to apply.

Question 2: For the previously described facility, if an existing 100 psi steam jacketed kettle is replaced with a new steam jacketed kettle and steam trap, is the steam trap on this system required to be accompanied by a strainer with blow-off valve and steam trap FDD device?

Answer: No. This steam trap supports replacement of existing equipment.

Question 3: For the previously described facility, if a new 100 psi steam jacketed kettle is added to this facility, is the steam trap on this system required to be accompanied by a strainer with blow-off valve and steam trap FDD device?

Answer: Yes. This steam trap is part of new process equipment installation. A strainer with blow-off valve would be required to protect the steam trap, along with a steam trap FDD device and the central console for displaying the state of all steam traps required to have FDD monitoring.

Question 4: For the previously described facility, a new hot water generator is installed. The main steam pressure is reduced to 5 psig upstream of the inlet of the hot water generator. Would a strainer with blow-off valve and steam trap FDD device be required for this system?

Answer: No. the steam trap in question is served by 5 psig steam, this is less than the 15 psig operating pressure threshold for each steam trap at which this requirements applies.

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11. Multifamily Building Requirements

11.1 Overview

This chapter covers the requirements for all dwelling units and common use areas in multifamily buildings for both newly constructed buildings and additions or alterations to existing buildings. Multifamily buildings include the following:

- A building of occupancy groups R-2, other than a hotel/motel building or timeshare property,
- A building of occupancy group R-3 that is a non-transient congregate residence, other than boarding houses of more than 6 guests and alcohol or drug abuse recovery homes of more than 6 guests, and
- A building of occupancy group R-4.

Single-family homes, duplexes, triplexes, and all townhouses (regardless of number of habitable stories) are subject to the single-family requirements and covered in the Residential Compliance Manual.

Spaces in multifamily buildings include both dwelling units and common use areas. Dwelling unit requirements apply to living, sleeping, eating, cooking, and sanitation spaces within a single unit. A single dwelling unit may include shared living spaces with multiple sleeping rooms, such as in a dormitory. Dwelling unit requirements covered in this chapter share few requirements with nonresidential buildings. Common use area requirements apply to spaces outside the dwelling unit that are shared by building owners, residents, and their guests. Spaces used by building managers and maintenance staff qualify as common use areas.

Due to the similarity of requirements for common use areas and nonresidential spaces, this chapter frequently references other chapters of the Nonresidential Compliance Manual for common use areas. All other occupancies in a mixed-use building are subject to the nonresidential requirements in Chapters 3 through 10.

The following building types are outside the scope of the Energy Code:

- Historical buildings, as defined by the in the California Historical Building Code (Title 24, Part 8). In alterations to historical buildings, replacement lighting fixtures that are not historic or replicas of historic fixtures must comply with applicable indoor and outdoor lighting requirements.
- At the discretion of the enforcement agency, temporary buildings, temporary outdoor lighting or temporary lighting in an unconditioned building, or structures erected in response to a natural disaster (Exception 2 to §100.0(a)). These buildings may also be exempt from mandatory requirements of the Energy Code.

Buildings being converted to a multifamily occupancy from another occupancy must comply with applicable requirements for additions or alterations to multifamily buildings.

Example 11-1

Question

Three stories of residential dwelling units are planned over a first story that includes retail and restaurant occupancies. Which occupancies need to comply with the multifamily standards?

Answer

The "R" occupancy (dwelling units and common use areas) will be subject to the MF requirements, the retail (occupancy "M") and restaurant (occupancy "A") are subject to the nonresidential standards. If using the performance approach, the combined energy budget is used to determine compliance.

Example 11-2

Question

Does a four-story townhouse need to comply with the single-family standards or multifamily standards?

Answer

Townhouses, regardless of number of habitable stories, are covered under the single-family standards.

Example 11-3

Question

An apartment building has three stories of apartments, and a garage on the first floor. What are the applicable compliance requirements?

Answer

Dwelling unit and common use area spaces must comply with the multifamily standards. The parking garage must meet applicable nonresidential lighting and covered process requirements.

11.1.1 Navigating This Chapter

Multifamily building dwelling unit requirements align closely with single-family requirements, while common use area requirements align closely with nonresidential requirements. All dwelling unit requirements are covered in the multifamily chapter. In some cases, headings for common use spaces reference other nonresidential chapters. Table 11-1 shows which chapter of this manual covers dwelling units vs. common areas.

Table 11-1: Compliance Manual and Standards Navigation by Dwelling Unit and Common Use Area

	Dwelling Unit	Common Use Area
Indoor Air Quality	Section11.4	Section 4.3
Space Heating and Cooling	Section 11.6.3	Chapter 4
Water Heating	Section 11.7.3	Section 11.7.3
Indoor Lighting	Section 11.8.2	Section 11.8.4
Outdoor Lighting	Section 11.8.2	Section 11.8.5
Electrical Power Distribution	N/A	Section 11.9
Covered Processes	N/A	Chapter 10
Electric-Ready	Section 11.12	N/A
PV and Battery Storage	Section 11.9	Section 11.9

Source: California Energy Commission

Each subchapter contains the following elements:

- A summary of what is new for the 2022 code cycle.
- Presentation of a specific topic in each subsection for newly constructed buildings
- A discussion of additions and alterations for existing buildings
- Compliance and enforcement
- Code in practice

Mandatory requirements, prescriptive requirements, and performance options are described within each subsection.

11.1.2 Code in Practice

Each technical chapter or subsection has a Code in Practice section with example projects that demonstrate compliance. The example projects are a two-story multifamily garden complex and a five-story mixed use building.

11.1.2.1 Two-Story Garden Complex

The two-story garden complex example has multiple eight-unit buildings with dwelling unit access from the building exterior and no interior common use areas. Building features and mechanical components include:

- Slab-on-grade ground floor
- Wood framed walls
- Vented attic
- Split heat pump with ducts in the attic and dropped soffit
- Individual water heaters
- Carport parking

11.1.2.2 Five-Story Mixed Use Building

The five-story mixed-use building example has ground floor retail and common use areas, with four residential floors and 88 dwelling units with above. Building features and mechanical components include:

- Concrete podium ground floor
- Below ground parking garage
- Wood frame construction on the second through fourth floors
- Metal frame construction on the fifth floor
- Flat roof with mechanical equipment and outdoor living space
- Split heat pump
- DOAS serving common use areas
- Central water heating serving the whole building

11.1.3 What's New for the 2022 Energy Code

The most significant change in the 2022 Energy Code affecting multifamily buildings is the consolidation of dwelling unit and common use area requirements into three standalone subchapters. These changes result in consistent requirements across multifamily buildings, while the 2019 Energy Code had separate requirements for multifamily buildings up to three habitable stories and buildings with four or more habitable stories. There are also changes in requirements related to indoor air quality, space conditioning, and domestic hot water. These are further described in the *What's New for the 2022 Energy Code* section and in each technical Section 11.3 through 11.9.

11.2 Compliance and Enforcement

This section covers the compliance forms and enforcement process applicable to multifamily buildings. Refer to Chapter 2 of the Nonresidential Compliance Manual for a more complete description of the compliance and enforcement process.

11.2.1 Compliance Documentation

Compliance documentation is required at the design phase (see Table 11-2), the construction phase (see Table 11-3), and the diagnostic testing and verification phase (see Table 11-4). All compliance documentation must be completed prior to the final inspection by the enforcement agency.

For multifamily buildings with three or fewer habitable stories, when a project includes a HERS verification requirement, all Certificates of Compliance, Certificates of Installation, and Certificates of Verification must be registered copies from an approved HERS registry. For multifamily buildings with four or more habitable stories, only the Certificates of Verification must be registered copies from an approved HERS registry. More details on field verification and diagnostic testing and the HERS provider data registry are in the *2022 Reference Residential Appendices and 2022 Reference Joint Appendices*, described below:

- Reference Joint Appendix JA7 – Data Registry Requirements
- Reference Residential Appendix RA2 – Residential HERS Verification, Testing, and Documentation Procedures
- Reference Residential Appendix RA3 – Residential Field Verification and Diagnostic Test Protocols

11.2.1.1 Design Phase

At the design phase, the Certificates of Compliance must be incorporated into the building plans submitted to the enforcement agency. Depending on the compliance approach, compliance documentation can also include the following worksheets:

- Area weighted average calculation worksheet (for roofs, walls, floors, and fenestration)
- Solar heat gain coefficient worksheet
- Cool roof and SRI worksheet

When the performance approach is used for compliance, additional worksheets are not required, since the Energy Commission-approved software performs the calculations and provides the documentation contained in all other worksheets.

When the prescriptive approach is used for additions and alterations, a shorthand version of the Certificates of Compliance must be submitted with the building plans, or with the permit application when no plans are required. Additions, alterations, and HVAC changeouts each have unique Certificates of Compliance.

For multifamily buildings up to three habitable stories for which compliance requires HERS verification, the Certificates of Compliance submitted to the enforcement agency must be a registered copy from an approved HERS registry. For a more detailed explanation of the HERS program and document registration, see Chapter 2 of the Nonresidential Compliance Manual.

Table 11-2 shows the Certificates of Compliance documents required, based on the permit application and number of stories.

Table 11-2: Certificates of Compliance by Application and Number of Stories

Application	Documentation Required for Buildings up to Three Habitable Stories when Applicable	Documentation Required for Buildings Four or more Habitable Stories when Applicable
Performance Approach	LMCC-PRF-01-E	NRCC-PRF-01-E
Electrical Power Distribution	LMCC-ELC-E	NRCC-ELC-E

Application	Documentation Required for Buildings up to Three Habitable Stories when Applicable	Documentation Required for Buildings Four or more Habitable Stories when Applicable
Envelope	LMCC-ENV-E	NRCC-ENV-E
Lighting – Indoor	LMCC-LTI-E	NRCC-LTI-E
Lighting - Outdoor	LMCC-LTO-E	NRCC-LTO-E
Lighting - Sign	LMCC-LTS-E	NRCC-LTS-E
Mechanical Systems	LMCC-MCH-E	NRCC-MCH-E
Water Heating Systems/Plumbing	LMCC-PLB-E	NRCC-PLB-E
Covered Processes	LMCC-PRC-E	NRCC-PRC-E
Solar	LMCC-SRA-E	NRCC-SRA-E

Source: California Energy Commission

11.2.1.2 Construction Phase Documentation

§10-103(a)3

The Certificates of Installation are separated into envelope, lighting, mechanical, plumbing, and solar categories. Most compliance features have a separate Certificate of Installation form that is specific to a particular trade (electrical, plumbing, HVAC, etc.). The Certificate of Installation forms are completed during the construction or installation phase by the contractors responsible for installing regulated energy features such as windows (fenestration), air distribution ducts and other requirements that affect building energy performance. The Certificates of Installation must be posted at the job site, kept with the building permit, or otherwise submitted to the enforcement agency.

When HERS verification of a feature is required, the builder or subcontractor performs the diagnostic test (Reference Residential Appendix RA3) of the installation to confirm compliance with the approved design requirements and the Energy Code. The Certificates of Installation for multifamily buildings with three or fewer habitable stories are registered with a HERS Registry and made available to the enforcement agency. Table 11-3 shows Certificates of Installation based on the application and number of stories.

Table 11-3: Certificates of Installation by Application and Number of Stories

Application	Documentation Required for Buildings up to Three Habitable Stories when Applicable	Documentation Required for Buildings Four or more Habitable Stories when Applicable
Electrical Power Distribution	LMCI-ELC-E (Common use area only)	NRCI-ELC-E
Envelope		NRCI-ENV-E
NonHERS	LMCI-ENV-E	
HERS	LMCI-ENV-(20 through 22)-HERS	
Indoor Lighting	LMCI-LTI-E (common use area only)	NRCI-LTI-E
Outdoor Lighting	LMCI-LTO-E (common use area only)	NRCI-LTO-E
Sign Lighting	LMCI-LTS-E (common use area only)	NRCI-LTS-E
Mechanical		NRCI-MCH-E
NonHERS	LMCI-MCH-E	
HERS	LMCI-MCH-(20 through 34)-HERS	
Domestic Hot Water/Plumbing		NRCI-PLB-E
NonHERS	LMCI-PLB-E	
HERS	LMCI-PLB-(21 through 22)-HERS	
Covered Process	LMCI-PRC-E	NRCI-PRC-E
Renewables		
Battery Storage		
Solar Photovoltaics	LMCI-SRA-E	NRCI-SRA-E
Solar Thermal		
Solar Ready		

Source: California Energy Commission

11.2.1.3 HERS Verification Documentation

§10-103(a)5

Within the Energy Code, some mandatory, prescriptive, and performance approach requirements may have HERS verification. HERS verifications involve HERS Raters and field technicians, and can involve Acceptance Test Technicians (ATTs).

Registration of Certificates of Compliance, Installation, and Verification is required for all multifamily buildings up to three habitable stories for which compliance requires HERS field verification. There are some exceptions for additions and alterations. When registration is required, compliance documents are electronically submitted to an approved HERS registry for registration and retention. Certificates of acceptance are not required to be registered with a HERS registry. Certificates of acceptance must be made available to the enforcement agency for all applicable inspections. Certificates of acceptance for lighting controls and mechanical systems acceptance testing must be completed through an Acceptance Test Technician Certification Provider (ATTCP).

Compliance documents submitted to a HERS registry must be certified by the appropriate responsible person (§10-103). The registry will assign a unique registration number to each document when completed, and certification (by electronic signature) is provided by the responsible person. The HERS registry will retain the registered documents, which are available via secure internet access to authorized users. This allows authorized users to provide copies of registered documents for enforcement agencies or other purposes as needed.

HERS Raters provide a separate registered certificate of verification for each dwelling unit that the rater determines has met the verification and/or diagnostic requirements for compliance. For multifamily buildings with three or fewer habitable stories, the HERS Rater must not sign a certificate of verification for a dwelling unit that does not have a registered certificate of installation that has been signed/certified by the installer. If the dwelling unit was approved as part of a sample group, the certificate of verification will include additional information that identifies whether the dwelling was tested or not tested within the sample group. The certificate of verification for the tested dwelling unit of a sample group will include the HERS verification results, while the certificate of verification for the non-tested dwelling units will not include the HERS verification results. Refer to Reference Residential Appendix RA2 for more details on the HERS verification and certificate of verification documentation procedures.

Table 11-4 shows certificates of verification and acceptance by the application and number of stories.

Table 11-4: Certificates of Verification and Acceptance by Application and Number of Stories

Application	Verifier	Documentation Required for Buildings up to Three Habitable Stories when Applicable	Documentation Required for Buildings Four or more Habitable Stories when Applicable
Envelope: Site-Built Fenestration	Contractor	LMCA-ENV-(02,03)-F	NRCA-ENV-(02,03)-F
Envelope: QII	HERS	LMCV-ENV-H	N/A

Application	Verifier	Documentation Required for Buildings up to Three Habitable Stories when Applicable	Documentation Required for Buildings Four or more Habitable Stories when Applicable
Common Use Area Indoor Lighting	ATT	LMCA-LTI-(02,03,04,05)-A	NRCA-LTI-(02,03,04,05)-A
Outdoor Lighting	ATT	LMCA-LTO-02-A	NRCA-LTO-02-A
Dwelling Unit Mechanical	HERS	LMCV-MCH-(04,24,27,32)-H	NRCV-MCH-(04,27)-H
Dwelling Unit Mechanical	ATT	N/A	NRCV-MCH-(04,27)-A
Common Use Area Mechanical	ATT	LMCA-MCH-(04,24,27,32)-A	NRCA-MCH-02 through 21-A
Hot Water Distribution	HERS Rater	LMCV-PLB-(21,22)-H	NRCV-PLB-(21,22)-H
Covered Processes	Contractor	LMCA-PRC-(02,03,12)-F	NRCA-PRC-(02,03,12)-F
Renewables Battery Storage Solar Photovoltaics Solar Thermal Solar Ready		TBD	TBD

Source: California Energy Commission

11.2.1.4 Compliance, Operating, Maintenance, and Ventilation Information to be Provided by Builder

§10-103(b)

At the completion of construction and before occupancy, the builder is required to leave the completed (signed and dated) compliance documentation in the building. This includes the certificates of compliance, installation, verification (if HERS verification was required) and acceptance. For multifamily buildings with three or fewer habitable stories, when HERS verification is required, the certificates of compliance, installation, and verification must be copies from the HERS Registry. For multifamily buildings with four or more habitable stories, only the certificates of verification must be registered with a HERS provider.

In addition to the compliance documentation, the builder must leave in the building operating and maintenance information for all applicable features, materials, components, and manufactured devices. The operation and maintenance information must contain the details needed to provide the building owner/operator/occupant with instructions on how to operate the building and systems in an energy-efficient manner that ensures satisfactory indoor air quality and to maintain it so that it will continue to operate efficiently. For individually owned units in a multifamily building, the documentation must be provided to the owner of the dwelling unit or to the individual(s) responsible for operating the feature, equipment, or device. Information must be for the appropriate dwelling unit or building. Paper or electronic copies of these documents are acceptable.

For mixed-use buildings with 10,000 square feet of total nonresidential space or greater, building commissioning will also be required for the nonresidential spaces only. See Chapter 13 for information about building commissioning requirements.

Example 11-4

The following questions relate to the requirement to provide documentation to the building owner/occupant at occupancy (as required by §10-103(b)):

Question

If the building is a condominium, can I photocopy the same certificate of compliance information for all units?

When the building is an apartment complex (not individually owned units), who gets the documentation?

If an apartment is converted to condominiums, does each owner/occupant receive copies of the documentation?

Answer

Photocopied information is acceptable. Electronic copies available through HERS providers and ATTCPs are another option for providing documentation to building owners/occupants. It must be obvious that the certificate of compliance applies to that dwelling unit. The features installed must match the features shown on the certificates of installation. If the compliance documentation is for a whole building, a photocopy of the certificate of compliance for that building must be provided. If individual compliance is shown for each unique dwelling unit, a photocopy of the documentation that applies to that dwelling unit must be provided. The copies may be in paper or electronic format.

The documentation and operating information are provided to the individual responsible for operating the feature, equipment, or device (typically the occupant). Maintenance information is provided to the person responsible for maintaining the feature, equipment, or device. This is either the owner or a building manager (§10-103(b)).

If, during construction, the building changes from an apartment to condominiums, each owner at occupancy would receive the documentation. If an existing apartment building changes to condominiums at a later date, the documentation requirements are triggered only by a building permit application requiring compliance with the Energy Code. Changing occupancy does not trigger compliance with the standards.

Example 11-5

Question

Can a certified HERS Rater who does the field verification and completes and signs the certificate of verification for a dwelling also perform the testing required of the builder or installer to certify compliance with the Title 24, Part 6 installation requirements on the certificate of installation?

Answer

Yes. This approach is allowed when the HERS Rater is doing field verification for every dwelling (100 percent testing), but it is not allowed when the rater performs verification using a designated sample group of dwellings. When 100 percent testing is used for HERS verification, the builder or the installer may use the information from the rater's verification or diagnostic test results when completing the certificate of installation. When doing so, builders or installers signing the certification statement on the certificate of installation are assuming responsibility for the information in the form and are certifying that the installation conforms to all applicable codes and regulations. The rater may not sign the form and cannot be assigned the responsibilities of the builder or installer, as stated on the certificate of installation and in regulations.

If the HERS Rater determines that the compliance requirements are not met, the HERS Rater will submit the data of the failed verification/testing into a HERS registry for retention. The builder or installer must make the needed corrections. Once corrections have been made and the rater determines that all compliance requirements are met, the builder or installer may certify the work by completing and signing the applicable section of the certificate of installation. The HERS Rater can complete the certificate of verification for the dwelling.

11.2.2 HERS Field Verification and Diagnostic Testing

For multifamily buildings up to three habitable stories, HERS verifications are performed by HERS Raters that are specially trained and certified by an Energy Commission-approved HERS provider to perform these services. Raters cannot be employees of the builder or contractor whose work they are verifying. Also, raters cannot have a financial interest in the builder's or contractor's business or advocate or recommend the use of any product or service that they are verifying. The training, quality assurance, and general oversight of the raters are conducted by Energy Commission-approved HERS providers.

For multifamily buildings with four or more habitable stories, dwelling unit leakage rate (compartmentalization) and kitchen exhaust airflow and sound rating must be verified by a HERS Rater. ERV/HRV and central ventilation shaft sealing must be verified by an acceptance test technician. Also, for multifamily buildings with four or more habitable stories, duct leakage testing, refrigerant charge testing, and airflow and fan watt draw measurements are only required to be completed by the person responsible for the installation. HERS-verified compliance credits available to multifamily buildings with three or fewer habitable stories are not available for multifamily buildings with four or more habitable stories.

The Energy Code's detailed reporting requirements are intended to provide design, construction, and enforcement personnel with the information to ensure that the energy features are properly installed. Each party is accountable to ensure that the features that they are responsible for are correctly installed. The HERS provider makes available via phone or internet a way for building officials, builders, HERS Raters, and other authorized users of the data registry to verify that the information displayed on copies of the submitted certificate(s) conforms to the registered document information on file in the registry for the dwelling unit.

11.2.2.1 Features Requiring HERS Verification

HERS verifications are required when certain regulated efficiency requirements or equipment features are installed. The following features require HERS verification:

- Building envelope air leakage
- Quality insulation installation (QII)
- Quality insulation installation for spray polyurethane foam
- Continuous whole-dwelling unit mechanical ventilation airflow
- Intermittent whole-building mechanical ventilation airflow
- Kitchen exhaust fan HVI or AHAM airflow, sound, and capture efficiency ratings
- Duct sealing
- Supply duct location, surface area, and R-value
- Low-leakage ducts in conditioned space
- Low-leakage air handlers
- Return duct design
- Air filter device design, MERV rating, and labeling
- Bypass duct prohibition
- Refrigerant charge in ducted split-system and ducted packaged unit air conditioners and heat pumps, and mini-split systems
- Refrigerant fault indicator display (FID)
- System airflow
- Air handler fan efficacy
- Energy efficiency ratio (EER)
- Seasonal energy efficiency ratio (SEER)
- Heat pump rated heating capacity
- Maximum rated total cooling capacity
- Evaporatively-cooled condensers
- Central fan-integrated ventilation cooling systems
- Zonal controls
- Parallel piping
- Compact hot water distribution system
- Pipe insulation credit

- Drain water heat recovery system
- Point of use
- Demand recirculation: manual control
- Demand recirculation: sensor control
- Multiple recirculation loop design for DHW systems serving multiple dwelling units

11.2.2.2 Verification, Testing, and Sampling

Field verification and diagnostic testing may be completed for each dwelling unit or for a sample of dwelling units. Sampling is permitted only when multiple dwelling units of the same type are constructed within the same multifamily development by the same subcontractor. Sampling may also be used for alterations to groups of dwelling units having the same features installed that require HERS verification, and where the same installing contractor has installed the features. More details are in RA2.6 and RA2.8, or NA1.6 and NA1.8 Sampling is also explained in the Residential Compliance Manual Chapter 2, section 2.5.2.

The HERS Rater must transmit and certify the test results to the HERS registry.

11.2.2.3 First Dwelling Unit Field Verification and Diagnostic Testing

The HERS Rater must diagnostically test and field-verify the first dwelling unit of each model of a multifamily development. To be considered the same model, dwelling units must have the same basic floor plan layout, energy design, and compliance features as shown on the certificate of compliance for each dwelling unit. Variations in the basic floor plan layout, energy design, compliance features, zone floor area, or zone volume, that do not change the HERS features to be tested or the heating or cooling capacity of the HVAC unit(s) must not cause dwelling units to be considered a different model. For multifamily buildings, variations in exterior surface areas caused by location of dwelling units within the building must not cause dwelling units to be considered a different model.

The HERS Rater will transmit the test results to the data registry. The HERS provider will make available a registered copy of each certificate of verification to the rater, the builder, the enforcement agency, and other authorized users of the data registry.

11.2.2.4 Group Sample Field Verification and Diagnostic Testing

For each unique dwelling unit model, after the first dwelling unit field verification and diagnostic testing are completed, the builder or the builder’s authorized representative determines which sampling procedure to use for the group of dwellings that require HERS field verification. There are two procedures for HERS verification compliance using group sampling: (1) sampling a closed group of up to seven dwelling units; and (2) sampling of an open group of up to five dwelling units. The group sampling requirements for each procedure are discussed in this section.

For multifamily buildings with three or fewer habitable stories, registration of all dwelling unit-level (as opposed to building-level) certificates of installation for at least one dwelling unit to the HERS registry is required to open a new group. Additional dwellings may be entered into the registry and included in an "open" group over a specific period, subject to transmittal/submittal of the certificate(s) of installation information to the registry for each additional dwelling. However, the group must not remain open to receive additional dwellings for a period longer than six months from the earliest date shown on any certificate of installation for a dwelling included in a group. A group may be closed at any time after the group has been opened at the option of the builder or builder's authorized representative. The size of a closed group may range from a minimum of two dwelling units to a maximum of seven dwellings. When a group is closed, no additional dwelling units must be added to the group. Whenever the HERS Rater for the group changes, a new group must be established.

Sampling of a closed group of up to seven dwelling units requires the following conditions to be met prior to receiving HERS compliance verification for the group:

1. All dwelling units in the sample group have been identified. Up to seven dwellings are allowed in a closed sample group.
2. Installation of all features that require HERS verification has been completed in all dwelling units in the group and registration of the certificates of installation for all dwelling units has been completed.
3. The group has been classified as a closed group in the data registry.
4. At the request of the builder or the builder's authorized representative, a rater will randomly select one dwelling unit from the closed sample group for field verification and diagnostic testing. If the dwelling unit meets the compliance requirements, this tested dwelling and each of the other non-tested dwelling units in the group will receive a registered certificate of verification.

Sampling of an open group of up to five dwelling units requires the following conditions to be met prior to receiving HERS compliance verification for the group:

1. At least one dwelling unit from the sample group has been identified. Up to five dwelling units are allowed in an open sample group.
2. Installation of all features that require HERS verification must be completed in all dwelling units. Registration of the certificates of installation for all dwelling units has been completed.
3. At the request of the builder or the builder's authorized representative, a rater will randomly select one dwelling unit from the open sample group for field verification and diagnostic testing. If the dwelling unit meets the compliance requirements, the tested dwelling and each of the other non-tested dwelling units must receive a registered certificate of verification. If there are fewer than five dwelling units, the group must be allowed to remain open and eligible to receive additional dwelling units. Dwelling units admitted to the open group after successful HERS compliance verification of the tested dwelling unit must also receive a registered certificate of verification as a non-tested dwelling unit, subject to receipt of the registered certificates of installation by the data registry for the dwelling. The group must be closed when it reaches the limit of five

dwelling units, when the six-month limit for open groups has been exceeded, or when the builder requests that the group be closed.

The rater must confirm that the certificates of installation have been completed as required and that the installer's diagnostic test results and the certificates of installation show compliance consistent with the certificate of compliance for the dwelling unit.

The rater must diagnostically test and field verify the selected dwelling unit and enter the test results into the data registry regardless of whether the results indicate a pass or fail. If the test fails, then the failure must be entered into the data registry, even if the installer immediately corrects the problem. In addition, any applicable procedures for resampling, full testing, and corrective action must be followed.

The provider will make available to the rater, the builder, the enforcement agency, and other approved users of the data registry a registered copy of the certificate of verification for the tested dwelling unit and for all other non-tested dwelling units in the group at the time of the sample test.

11.2.2.5 Installer Requirements and HERS Procedures for Alterations to Buildings up to Three Habitable Stories

When compliance for an alteration requires field verification and diagnostic testing by a certified HERS Rater, the building owner may choose for field verification and diagnostic testing to be completed for each dwelling unit or as part of a designated sample group of dwelling units for which the same installing company has completed work that requires testing and field verification for compliance. The only alterations that require HERS testing and verification are HVAC changeouts in multifamily buildings with three or fewer habitable stories. The building owner or agent of the building owner must complete the applicable portions of a shorthand version of the certificate of compliance for the appropriate climate zone. When compliance requires verification, the building owner or agent must arrange for transmittal/submittal of the certificate of compliance to the data registry, identifying the altered HVAC system and features that require verification. The building owner must submit an approved/signed copy of the certificate of compliance to the rater.

When the installation is complete, the person responsible for performing the installation must complete the certificates of installation. All required certificates of installation must be registered with an approved data registry when field verification and diagnostic testing are required.

After verifying that the certificate of compliance and all required certificates of installation are completed, signed, and registered, the rater must verify compliance. If group sampling is used for compliance, the sampling procedures described in Reference Residential Appendix RA2.6.3.3 and RA2.8, for sampling of a closed group of up to seven dwelling units must be used. The installing company may request a sample group that has fewer than seven dwelling units. Resampling, full testing, and corrective action must be completed, if necessary, as specified by Reference Residential Appendix RA2.6.4.

The enforcement agency cannot approve the alteration until the agency has verified completed, signed, and registered certificate of compliance, certificates of installation, and certificates of verification documentation for the altered HVAC system.

Third-party quality control programs, as specified in Reference Residential Appendix RA2.7, may be used with alterations and must be limited to closed sample group sizes of 30 dwelling units (HVAC systems) or fewer. When a third-party quality control program is used, the enforcement agency may approve compliance based on the certificates of installation, where data checking has indicated that the unit complies, on the condition that if the required HERS verification procedures determine that resampling, full testing, or corrective action is necessary, such work must be completed.

11.2.3 Acceptance Testing

For common use areas and dwelling units in multifamily buildings with four or more habitable stories, as well as site-built fenestration in all multifamily buildings, acceptance testing by a field technician or ATT may be required. Refer to Chapter 14 for an explanation of acceptance testing requirements. Multifamily features requiring acceptance testing include:

- Site-built fenestration
- Common use area mechanical systems:
  - Outdoor air ventilation
  - Constant volume, single zone air conditioning and heat pump unit controls
  - Duct systems
  - Air economizers
- Whole-dwelling unit mechanical systems in buildings four or more habitable stories:
  - Dwelling unit ventilation systems
  - Dwelling unit enclosure leakage (compartmentalization)
  - Central ventilation duct leakage
  - Central ventilation heat recovery or energy recovery systems
- Common use area indoor and outdoor lighting controls
- Parking garage ventilation
- Elevator lighting and ventilation

11.3 Building Envelope Requirements

This chapter covers building envelope features and compliance strategies for newly constructed multifamily buildings and additions and alterations to multifamily buildings. It highlights the energy code requirements that affect the design of the building envelope. Multifamily envelope requirements, except for HERS requirements, apply to all dwelling units and common use areas in all multifamily buildings. HERS envelope requirements apply to multifamily buildings up to three habitable stories. Nonresidential occupancies in a mixed-use building must comply with nonresidential envelope requirements outlined in Chapter 3.

This chapter is organized by building envelope component and includes:

- A description of opaque envelope requirements related to air sealing and leakage, insulation, roofing products, radiant barriers, air barriers, vapor retarders, and attic ventilation. The opaque envelope includes roof, wall, and floor assemblies.
- A description of fenestration requirements for U-factor, solar heat gain coefficient (SHGC), visible transmittance (VT), and window area.
- Verification requirements, including those for QII.
- Additions and alterations requirements

Table 11-5 summarizes the location of mandatory, prescriptive, and performance requirements in the multifamily standards and in the compliance manual.

Table 11-5: Overview of Envelope Requirements in the Energy Code and Compliance Manual Organization

Envelope Component	Mandatory	Prescriptive	Performance	Compliance Manual
Ceiling and Roof Insulation	§§110.8(a) - (d), 110.8(h),160.1(a)	§170.2(a)1, Table 170.2-A	§170.1	3.2.3.1, 3.2.4.1
Radiant Barrier	§110.8(j)	§170.2(a)1C, Table 170.2-A, RA4.2.1	§170.1	11.1.9.1
Roofing Products	§§10-113, 110.8(i),	§170.2(a)1A, Table 170.2-A	§170.1	3.2.4.1,
Wall Insulation	§§110.8(a) - (c), 160.1(b)	§170.2(a)2, Table 170.2-A	§170.1	3.2.3.1, 11.1.9.3
Raised Floor Insulation	§§110.8(a) - (d), 110.8(g), 160.1(c)	§170.2(a)5, Table 170.2-A	§170.1	3.2.3.1, 3.2.8.1
Slab Insulation	§110.8(g), Table 110.8-A	§170(a)5B, Table 170.2-A	§170.1	11.1.9.5
Opaque Doors	§§10.111, 110.6(a)	§170.2(a)4, Table 170.2-A	§170.1	11.1.9.6
Vapor Retarder	§160.1(d)	N/A	N/A	11.1.9.7

Envelope Component	Mandatory	Prescriptive	Performance	Compliance Manual
Air sealing and air leakage	§§110.7, 160.1(f)	N/A	N/A	11.1.9.8
QII	N/A	§170.2(a)6, Table 170.2-A, RA3.5	§170.1	11.1.9.9
Fenestration	§§10-111, 10-112, 110.6(a), Table 110.6-A, §160.1(e)	§170.2(a)3, Table 170.2-A	§170.1	3.3.1, 3.3.2, 11.1.10,
Daylighting	N/A	§170.2(b)	§170.1	3.3.4.2E, 11.1.11
Additions	§160.1	§180.1(a)1	§180.1(b)	11.1.12.1
Alterations	§180.2(a)	§180.2(b)1	§180.2(c)	11.1.12.2

Source: California Energy Commission

11.3.1 What's New for the 2022 Energy Code

The *2022 Building Energy Efficiency Standards* for multifamily buildings consolidate requirements for all multifamily building types, with requirements based on assembly or fenestration type rather than number of stories. This reclassification allows for better alignment of energy efficiency requirements with fire safety and structural requirements. Table 170.2-A of the Energy Code captures the updated requirements for all multifamily buildings. Notable 2022 envelope changes include:

- Buildings up to three habitable stories have a new prescriptive insulation Option D for roof assemblies without attics.
- Buildings with four stories or more with attics have new prescriptive Options B or C for roof and ceiling insulation.
- Prescriptive roof reflectance and emissivity requirements depend on roof options Option B, C, or D
- Prescriptive roof reflectance requirements increased to 0.63 in climate zones 9-11 and 13-15 for buildings with low-sloped roofs and no attic.
- Mandatory and prescriptive wall U-factors are recategorized by assembly type and by fire rating for framed assemblies. This results in many climate zone-specific adjustments. The greatest changes include reduced U-factors for framed walls in multifamily buildings with four or more stories.
- Prescriptive fenestration properties, including U-factor, solar heat gain coefficient (SHGC), and visual transmittance (VT), depend on categorization into curtainwall, Class AW, or all other fenestration, and vary by climate zone. There is no distinction between fixed and operable windows. The greatest change is for fenestration in multifamily buildings with four or more stories that fall into all other fenestration category (not curtainwall or Class AW).
- Prescriptive requirements for fenestration properties in multifamily building additions and alterations depend on window classification (curtainwall, Class AW, or all other).

- Prescriptive fenestration area is limited to both 40 percent window-to-wall ratio and 20 percent window-to-floor ratio.

11.3.2 Opaque Envelope

This section of the building envelope chapter addresses the requirements for air leakage, roof products, roof and ceiling insulation, radiant barriers, and vapor retarders.

11.3.2.1 General Insulation Requirements

§110.8(a) – (c), 110.8(g)

Insulation materials must be certified by the Department of Consumer Affairs, Bureau of Household Goods and Services and listed in the Directory of Certified Insulation Materials. Urea formaldehyde foam insulation, flame spread index and smoke development index must meet requirements for multifamily and nonresidential buildings.

11.3.2.2 Ceiling and Roof Insulation

11.3.2.3 Mandatory Requirements

A. Attic Roof

§160.1(a)1

Roof/ceiling construction assemblies with an attic space must have at least R-22 insulation between wood framing members or a maximum U-factor of 0.043. Some areas of the roof/ceiling can be greater than the maximum U-factor if other areas have lower U-factors such that the weighted average U-factor for the overall ceiling/roof is 0.043 or less. Metal framed assemblies must also have a weighted U-factor of 0.043 or less.

If insulation is not penetrated by framing, such as rigid insulation laid over a structural deck, then the rigid insulation can have a rated R-value of less than R-22 so long as the total roof/ceiling assembly U-factor is not greater than U-0.043.

Loose fill insulation must be blown in evenly and insulation levels must be documented on the certificate of installation. The insulation level can be verified by checking that the depth of insulation conforms to the manufacturer’s coverage chart for achieving the required R-value. The insulation also must meet the manufacturer’s specified minimum weight per square foot for the corresponding R-value.

B. Non Attic Roof

§160.1(a)2 and 3

For roof/ceiling construction assemblies without an attic space, the maximum weighted average U-factor is 0.098 for metal building and 0.075

for wood framing and others. If insulation is installed at the roof, vents or openings that penetrate the roof deck to the outdoor are prohibited.

Regardless of whether or not there is an attic space, insulation mustmust be installed in direct contact with the air barrier.

C. Wet Insulation Systems

§110.8(h)

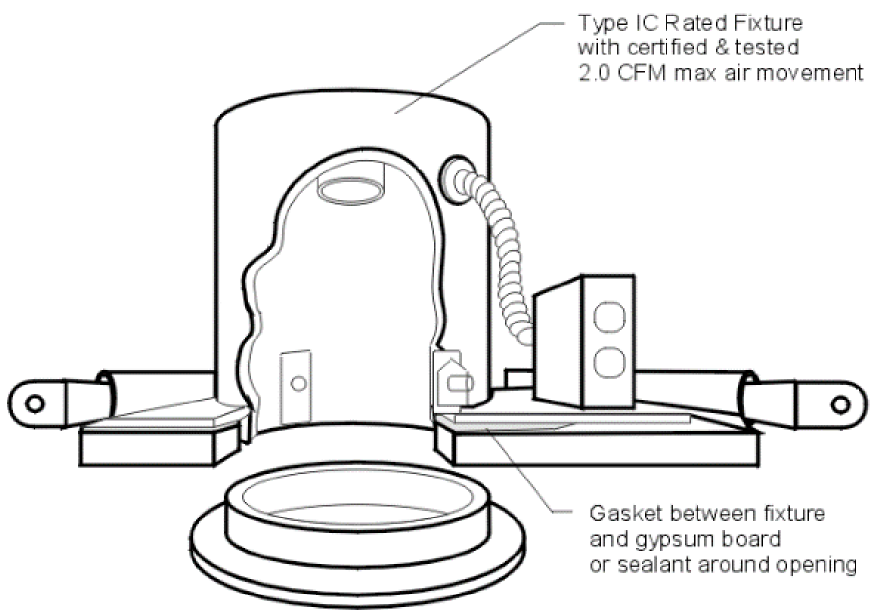
Wet insulation systems are covered in Section 3.2.4.1 for multifamily and nonresidential buildings.

D. Recessed Luminaires

§160.5(a)1C

Luminaires recessed in insulated ceilings can create thermal bridging through the assembly. Not only does this degrade the performance of the ceiling assembly, but it can permit condensation on a cold surface of the luminaire if exposed to moist air, as in a bathroom.

Figure 11-1. IC-Rated Luminaire (Light Fixture)



Luminaires recessed in insulated ceilings must meet three requirements.

1. They must be listed as defined in the Article 100 of the California Electric Code for zero clearance insulation contact (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Code Council (ICC). This enables insulation to be in direct contact with the luminaire.

2. The luminaire must have a label certified as per §160.5(a) for airtight (AT) construction. Airtight construction means that leakage through the luminaire will not exceed 2.0 CFM when exposed to a 75 Pa pressure difference, when tested in accordance with ASTM E283.
3. The luminaire must be sealed with a gasket or caulk between the housing and ceiling.

11.3.3 Prescriptive Requirements

§170.2(a)1B, Table 170.2-A

The Energy Code is designed to offer flexibility to builders and designers of multifamily newly constructed buildings in terms of achieving the intended energy efficiency targets. Thus, the Energy Code offers several compliance options for roof insulation in multifamily buildings, as shown in Table 11-6.

Table 11-6: Summary of Multifamily Roof Insulation Options

Roof / Ceiling Insulation Option	Attic Space	Below Roof Deck Insulation	Ceiling Insulation	Radiant Barrier	Duct and Air Handler Location
B	Yes, ventilated	Required in climate zones 4 and 8-16	Yes	Required in certain climate zones	Allowed in ventilated attic
C	Yes, ventilated	Not required	Yes	Required in certain climate zones	Within conditioned space
D	No	As needed to meet assembly U-factor requirements	As needed to meet assembly U-factor requirements	N/A	Within conditioned space

Source: California Energy Commission

Option B has a vented attic space and uses a combination of ceiling insulation and below roof deck insulation.

Option C also has a vented attic space but uses ceiling insulation only.

Option D has no attic space and uses U-factor requirements instead of insulation levels.

The prescriptive requirements for Option B and Option C assume that the building is built with the following construction practices:

1. The attic is ventilated with an appropriate free vent area as described below.
2. The roof is constructed with standard wood rafters and trusses.

3. For Option B, the outermost layer of the roof construction is either tiles or a roofing product installed with an air gap between it and the roof deck.
4. The air handler and ducts are in the ventilated attic for Option B and are otherwise in conditioned space for Option C.
5. The air barrier is located at the ceiling (except cathedral and sealed attic roof/ceiling systems).

If a building design does not meet all of these specifications, for example an unvented attic, it must comply through the performance approach as described in Section 11.1.9.10.

Section 170.2 requires different values of roof and ceiling insulation, depending on whether Option B or Option C is chosen. Table 11-7 shows a prescriptive requirements checklist for each option based on Table 170.2-A.

Table 11-7: Prescriptive Insulation Options

Ventilated Attics	**Ventilated Attics with Ducts in Conditioned Space**	**No Attic**
Option B	**Option C**	**Option D**
☐ Vented attic ☐ R-19 (CZ 4, 8-9, 11-15) or R-13 (CZ 10, 16) **below roof deck** batt, spray in cellulose/fiberglass secured with netting, or spray foam ☐ R-38 (CZ 1, 2, 4, 8-16) ceiling insulation or R-30 (CZ 3 and 5-7) ☐ Radiant barrier (CZ 2, 3, 5-7) ☐ Air space between roofing and the roof deck	☐ Vented attic ☐ R-38 (CZ 1, 11-16) ceiling insulation or R-30 (CZ 2-10) ☐ R-6 or R-8 ducts (climate zone-specific) ☐ Radiant barrier (CZ 2-15)	☐ No attic space ☐ Maximum U-factor of 0.041 for metal buildings ☐ Maximum U-factor of 0.028 (CZ 1-2, 4, 8-16) or 0.034 (CZ 3, 5-6) or 0.039 (CZ7)

Source: California Energy Commission

Below Roof Deck Insulation (**Option B).** In a vented attic, air-permeable or air-impermeable insulation (batt, spray foam, loose-fill cellulose, or fiberglass) should be placed directly below the roof deck between the truss members and secured in place to provide a thermal break. Figure 11-2 shows an example of insulation details in an Option B attic. Insulation must be in direct contact with the roof deck and secured by the insulation adhesion, facing, mechanical fasteners, wire systems, a membrane material, or netting. Batts supported with cabling or other mechanical methods from below mustmust have supports that are less than or equal to 16” apart and no further than 8” from the end of the batt. Figure 11-3 shows the placement and provides example attachment methods for below-deck insulation.

When batt thickness exceeds the depth of the roof framing members, full-width batts must be used to fit snugly and allow batts to expand beyond the framing members. Full coverage of the top chord framing members by insulation is recommended as best practice but is not required.

Figure 11-2: Details of Option B Assembly

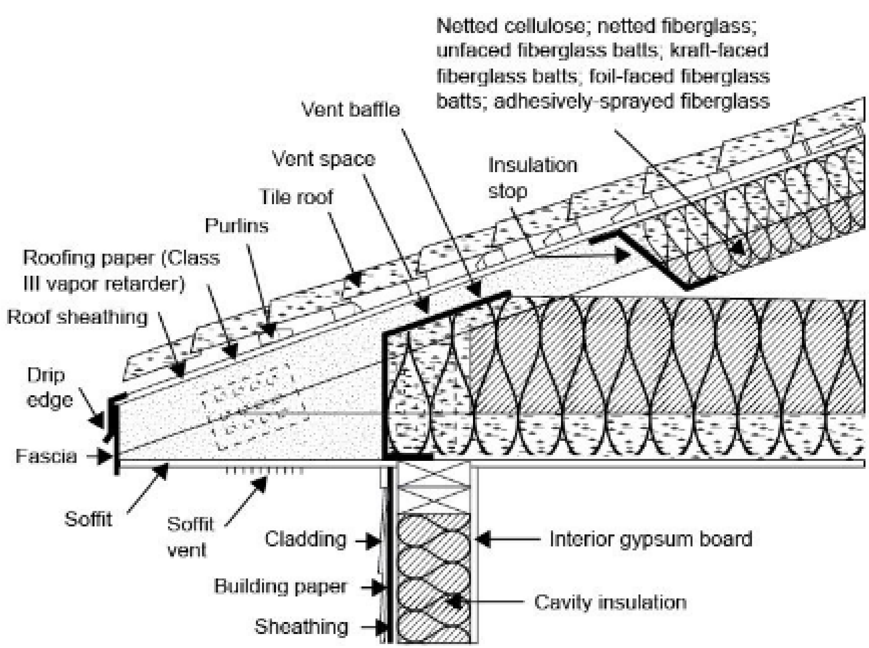
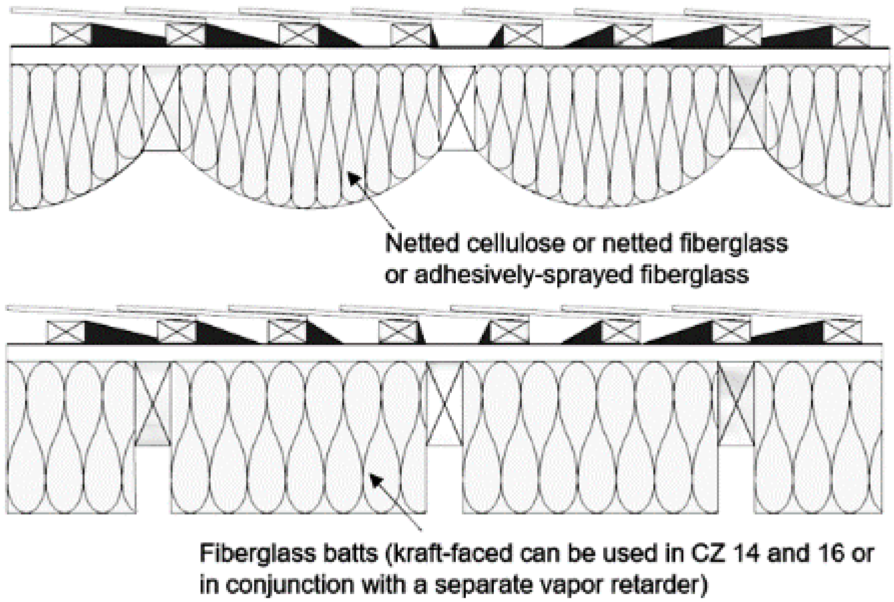


Figure 11-3: Placement of Insulation Below the Roof Deck



When insulation is installed below the roof deck to meet the prescriptive requirements of Option B, a radiant barrier is not required.

Vapor Retarders (Option B). Attic vapor retarders are not required by the Energy Code in most climates when using spray foam, blown-in insulation, or unfaced batts, and when sufficient attic ventilation is maintained. Although not required, the use of vapor retarders can provide additional security against possible moisture buildup in attic and framed assemblies. In climate zones 14 and 16, a Class I or Class II vapor retarder must be used to manage moisture[1] as stated in the California Building Code (CBC), Title 24, Part 2.5, §R806.2.

Attic Ventilation (Options B and C)

Proper attic ventilation occurs at two points at the roof: the soffit (or eave) vents and the ridge vents.

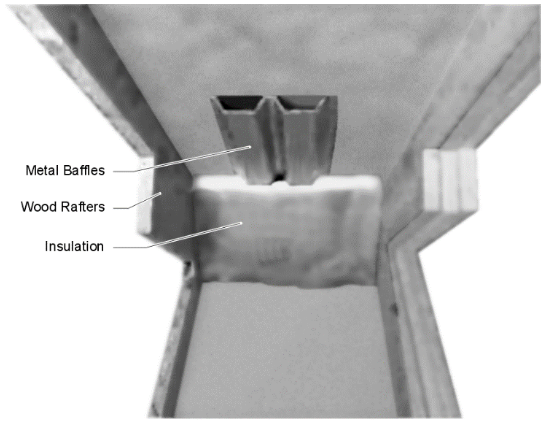
When installing insulation below the roof deck, vent baffles and insulation barriers should be used to maintain proper ventilation space. Proper airflow through the space helps remove moisture and prevents any associated issues.

Where ceiling insulation is installed next to eave or soffit vents, a rigid baffle should be installed at the top plate to direct ventilation air up and over the ceiling insulation. (See Figure 11-4.) The baffle should extend beyond the height of the ceiling insulation and should have sufficient clearance between the baffle and roof deck at the top. There are several acceptable methods for maintaining ventilation

. [1] Insulation Contractors Association of America. (2004). Technical Bulletin No. 6 Use of Vapor Retarders.

air, including preformed baffles made of cardboard or plastic. In some cases, plywood or rigid foam baffles are used.

Figure 11-4: Baffles at the Eave in Attics



The California Building Code (CBC) requires a minimum vent area to be provided in roofs with attics, including enclosed rafter roofs that create cathedral or vaulted ceilings. Check with the local building jurisdiction to determine which of the two CBC ventilation requirements are to be followed:

1. CBC, Title 24, Part 2, Vol. 1, Section 1203.2 requires that the net-free ventilating area mustmust not be less than 1/300 of the area of the space ventilated.
2. CBC, Title 24, Part 2.5, Section R806.2 requires that the net-free ventilating area mustmust not be less than 1/150 of the area of the space ventilated. This ratio may be reduced to 1/300 if a ceiling vapor retarder is installed in climate zones 14 and 16.

If meeting Option 1 above, a minimum of 40 percent and not more than 50 percent of the vents must be located at least 3 feet (ft.) above the eave or cornice vents in the upper portion of the space being ventilated.

Insulation mustmust not block the free flow of air, and a minimum 1-inch air space mustmust be provided between the insulation and the roof sheathing and at the location of the vent.

Ventilated openings are covered with corrosion-resistant wire cloth screening or similar mesh material. When part of the vent area is blocked by meshes or louvers, the resulting net-free area of the vent must be considered to determine if ventilation requirements are met.

Many jurisdictions in California are covered by Wildland Urban Interface (WUI) regulations where specific requirements for construction materials must be used to improve building fire resistance. These regulations require special vents that are expressly tested to resist the intrusion of flame and embers. Check with the building department to ensure compliance with local codes.

Ducts and Air Handlers Located in Conditioned Space. Ducts may be located and verified to be in conditioned space instead of installing insulation at the roof deck. If complying with this option, ceiling and duct insulation must be installed at the values specified in Table 170.2-B for Option C, and a radiant barrier is required in most climate zones.

HERS Verification (Option C). Locating ducts in conditioned space does not alone qualify for this requirement; a HERS Rater must test and verify for low leakage ducts within conditioned space and verify that the ducts are insulated to a level required in Table 170.2-K of the Energy Code.

Design strategies that can be used to prescriptively comply with Option C include dropped ceilings (dropped soffit), plenum or scissor truss to create a conditioned plenum box, and open-web floor truss. The ducts and equipment must be within the air barrier of the building. Locating ducts within an unvented attic does not meet Option C requirements.

Ceiling Insulation (Options B and C). Insulation coverage should extend far enough to the outside walls to cover the bottom chord of the truss. However, insulation should not block eave vents in attics because the flow of air through the attic space helps remove moisture that can build up in the attic and condense on the underside of the roof deck. This can cause structural damage and reduce the effectiveness of the insulation.

Based on area-weighted averaging, ceiling insulation may be tapered near the eave, but it must be applied at a rate to cover the entire ceiling at the specified level. An elevated truss, or raised heel truss, is not required but may be desirable in some applications.

11.3.3.1 Performance Approach

In the performance approach, the standard design is based on the roof type. If the proposed design has an attic, prescriptive requirement Option B serves as the standard design, and Option D if there is no attic. An unvented attic must comply through the performance approach.

Example 11-6: Unventilated Attics

Question

Does an unventilated attic with insulation at the roof deck comply under the prescriptive requirements?

Answer

No. The entire attic must be a ventilated space with the building air barrier located at the ceiling with standard trusses to comply with the prescriptive requirements. This project must comply through the performance approach.

Example 11-7: Insulation Above the Roof Deck

Question

Does a ventilated attic with insulation above the roof deck comply under the prescriptive requirements?

Answer

No. The insulation must be located below the roof deck between the roof rafters to comply with the prescriptive requirements. If insulation is above the roof deck, the project must comply through the performance approach.

Example 11-8: Asphalt Shingles

Question

A building with asphalt shingle roofing, having no air gap, has a ventilated attic with insulation installed below the roof deck between the roof rafters (HPVA) and at the ceiling meeting prescriptive insulation levels. Does this building comply with the prescriptive requirements?

Answer

No. The roofing product must be of a type that is installed with an air gap between the product and the roof deck, such as concrete tile, to comply with the prescriptive requirements. If a roofing product with no air gap between the product and the roof deck is installed, the project must comply through the performance approach.

Example 11-9: Gable Ends in High Performance Ventilated Attics

Question

In addition to the roof underdeck, do gable end walls in high performance ventilated attics (HPVA) need to be insulated?

Answer

No. Gable end walls do not need to be insulated when designing and installing a HPVA.

Example 11-10: Attic Insulation Placement

Question

When installing roof/ceiling insulation, does the insulation need to be installed on the entire roof/ceiling, including areas over unconditioned space?

Answer

It depends. The insulation should be installed at the roof/ceiling in one of the following ways:

(1) If the attic is an open or undivided space, then the entire roof/ceiling should be insulated. This includes portions of the roof/ceiling over an unconditioned space such as a garage.

(2) If the attic has a continuous air barrier separating the attic over unconditioned space from the attic over conditioned space, then only the portions of the roof/ceiling over conditioned space should be insulated. It is recommended, but not required, that the air barrier also be insulated.

11.3.3.2 Radiant Barrier

11.3.3.3 Mandatory Requirements

§110.8(j)

The radiant barrier is a reflective material that reduces radiant heat transfer into the attic from solar heat gain in the roof. Radiant barriers must have an air space next to the foil side to provide its energy benefit. When a radiant barrier is installed, the product must meet mandatory requirements in §110.8(j). The radiant barrier must have an emittance of 0.05 or less. The product must be tested according to ASTM C1371 or ASTM E408 and must be certified by the California Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation and listed in its Consumer Guide and Directory of Certified Insulation Material, at https://bhgs.dca.ca.gov/consumers/ti_directory.pdf.

11.3.3.4 Prescriptive Requirements

§170.2(a)1C, RA4.2.1

The prescriptive requirements call for Option C vented attics to have a radiant barrier in climate zones 2 through 15, while Option B vented attics require a radiant barrier in climate zones 2, 3, and 5 through 7.

Installation. The most common way of meeting the radiant barrier requirement is to use roof sheathing that has a radiant barrier bonded to it by the manufacturer. Some oriented strand board (OSB) products have a factory-applied radiant barrier. The sheathing is installed with the radiant barrier (shiny side) facing down toward the attic space.

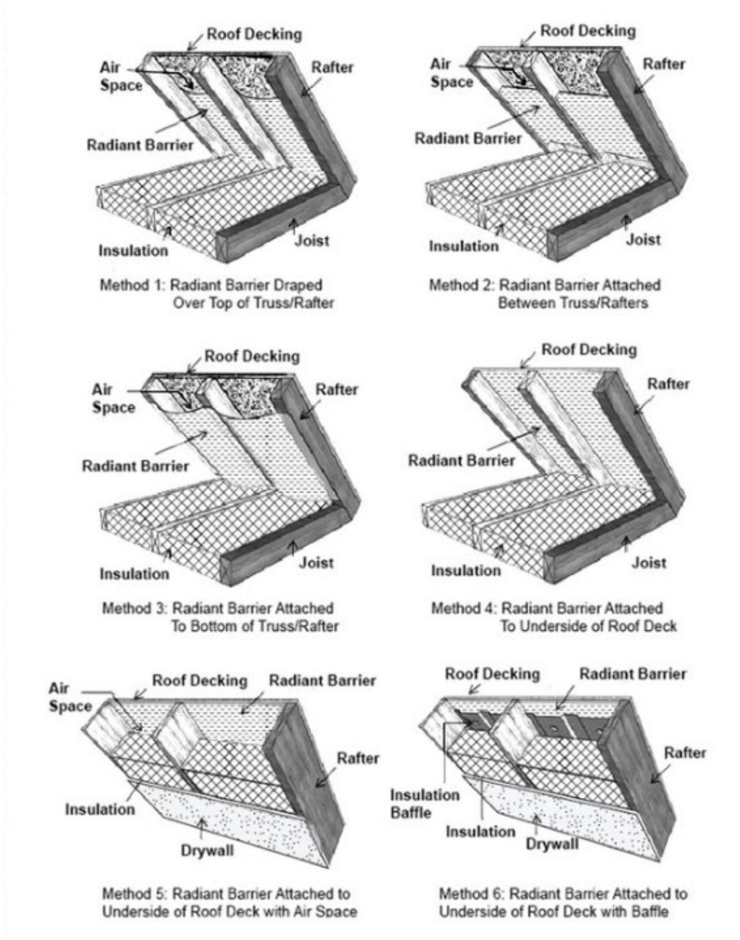
Alternatively, a radiant barrier material that meets the same ASTM test and moisture perforation requirements that apply to factory-laminated foil can be field-laminated. Field lamination must use a secure mechanical means of holding the foil-type material to the bottom of the roof decking such as staples or nails that do not penetrate all the way through the roof deck material. Roofs with gable ends must have a radiant barrier installed on the gable ends to meet the radiant barrier requirement.

Other acceptable methods are to drape a foil type radiant barrier over the top of the top chords before the sheathing is installed, stapling the radiant barrier between the top chords after the sheathing is installed, and stapling the radiant barrier to the underside of the truss/rafters (top chord). For these installation methods, the foil must be installed with spacing requirements as described in Reference Appendices, Residential Appendix RA4.2.1.

Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces, particularly when roof sheathing is installed that does not include a laminated foil-type radiant barrier. Radiant barrier foil material may be field-laminated after the sheathing has been installed by laminating the foil to the roof sheathing between framing members. This construction type is described in the Residential Reference Appendices RA4.2.1.1. See Figure 11-5 for drawings of radiant barrier installation methods.

For closed rafter spaces, such as a cathedral ceiling, the required air space for radiant barriers mustmust be provided and must meet the ventilation requirements of the California Building Code (CBC), Title 24, Part 2.5, Section R806.1.

Figure 11-5: Methods of Installation for Radiant Barriers



11.3.3.5 Performance Approach

In the performance approach, radiant barriers are modeled apart from the U-factor. The duct efficiency also is affected by the presence of a radiant barrier when using the performance approach.

11.3.3.6 Roofing Products

11.3.3.7 Roofing Products Mandatory Requirements

§10-113, 110.8(j)

See Section 3.2.4.1 for mandatory requirements for roofing products, rating and labeling, and field-applied liquid coatings applicable across multifamily and nonresidential buildings.

11.3.3.8 Roofing Products Prescriptive Requirements

§170.2(a)1A, Table 170.2

Energy-efficient cool roofs are prescriptively required based on the roof slope and climate zones. The prescriptive requirements are based on aged solar reflectance and thermal emittance, or solar reflectance index (SRI), as summarized in Table 11-8. For steep-sloped roofs, the requirements also differ depending on whether roof/ceiling Option B, C, or D is selected. If a cool roof is being installed to comply with the Energy Code, it must meet the mandatory product and labeling requirements of Section 110.8(i) of the Energy Code.

Table 11-8: Prescriptive Cool Roof Requirements

Roof Type	Climate Zone	Minimum Three-Year Solar Reflectance	Minimum Thermal Emittance	Minimum SRI
Steep-sloped, Option B and C	10-15	0.20	0.75	16
Steep-sloped Option D	2-15	0.20	0.75	16
Low-sloped Option B and C	13 and 15	0.63	0.75	75
Low-sloped Option D	9-11 and 13-15	0.63	0.75	75

Source: California Energy Commission

There are two exceptions to meeting these prescriptive requirements:

1. Roof area with building-integrated photovoltaic panels or building-integrated solar thermal panels.
   OR
2. Roof constructions that have a weight of at least 25 pounds per square foot, including EPDM with stone ballast and slate roofing.

11.3.3.9 Roofing Products Performance Approach

The performance approach can be used to trade off the prescriptive cool roof requirements or increase solar reflectance or reduce emittance for additional credit.

If a manufacturer does not obtain a Cool Roof Rating Council (CRRC) certificate for its roofing products, the following default aged solar reflectance and thermal emittance values must be used for compliance:

1. For asphalt shingles: 0.08 aged solar reflectance (ASR) and 0.75 thermal emittance (TE)
2. For all other roofing products: 0.10 aged ASR and 0.75 TE

11.3.3.10 Wall Insulation

Requirements for wall U-factor and insulation are grouped by a combination of factors: wall assembly fire rating and construction type. In prescriptive requirements, all framed walls regardless of the framing material (wood, metal, or others) are subdivided into those with one-hour or lower fire rating and those with higher than one-hour fire rating. This allows high-fire rating (one-hour or higher) wall types, which have constructability limitations and are more costly to insulate, to adhere to less stringent U-factor requirements than walls with lower fire ratings (lower than one-hour).

Additionally, metal buildings and mass walls have their own subcategories for requirements.

11.3.3.11 Wall Insulation Mandatory Requirements

§160.1(b)

Above grade walls separating conditioned spaces from other spaces must adhere to the requirements below, based on the material, size, and location of the wall assemblies:

2x4 inch wood-framed walls above grade mustmust have a U-factor not exceeding 0.102. This requirement is met with at least R-13 insulation installed in the cavities between framing members.

2x6 inch or greater wood-framed walls above grade mustmust have a U-factor not exceeding 0.071. This requirement is met with at least R-20 insulation installed in the cavities between framing members.

Demising partitions and knee walls. Demising and knee walls must not exceed minimum U-factor requirements of 0.099 for wood framing and 0.151 for metal framing.

Metal building, mass walls, and spandrel panels and curtain wall. Each of the wall construction must not exceed the U-factor requirement in Table 11-9.

All other wall types (not listed) above grade must meet a maximum U-factor of 0.102.

Table 11-9: Wall Construction U-Factor Requirements

Wall Construction	U-factor Not to Exceed
Metal Building	0.113
Metal Framed	0.151
Light Mass Wall	0.440
Heavy Mass Wall	0.690
Spandrel Panel and Curtain Wall	0.280

Source: California Energy Commission

11.3.3.12 Wall Insulation Prescriptive Requirements

§170(a)2, Table 170.2-A

The prescriptive requirements in Table 170.2-A for low fire rating (0-hour or 1-hour) framed walls are a U-factor of 0.051 in climate zones 1-5 and 8-16, and a U-factor of 0.065 in climate zones 6 and 7.

The U-factor requirements for high fire rating walls (1-hour or greater) are a U-factor of 0.059 for climate zones 1-5, 8-10, 12, and 13, and a U-factor of 0.051 for climate zone 11 and 14-16. U-factor requirements for climate zones 6 and 7 are 0.065 for both high fire rating and low fire rating framed walls.

A wall's fire-resistance rating is determined by the fire code and is measured in hours. Chapter 6 of the California Building Code (CBC) describes fire-resistance rating in detail, and a building's specific rating is ultimately decided upon by the local building official. The fire rating for a building's exterior walls depends on the construction type, based on the building's number of stories, building height, occupancy type, and fire-suppression system type. A wall's fire-resistance rating can also vary due to fire-separation distance, though for residential occupancy types, fire-separation distance never changes a wall's rating from 1-hour to 2-hour (or more). Code officials use CBC Tables 601, 602, 504.3 and 504.4 in combination to make the wall fire-rating determinations. The determination method is generally well understood, and fire-resistance rating info is readily available from the building's architect. Generally, higher buildings with six or more stories and heavy-timber buildings have high fire-ratings, while low or mid-rise buildings of five or fewer stories have a low-fire rating. In most cases, all walls of a specific building will fall under one of the two categories used in Table 170.2-A.

The designer may choose any wall construction from Reference Appendices, Joint Appendix JA4 (Tables 4.3.1 and 4.3.4) that has a U-factor equal to or less than the prescribed level, depending on the climate zone.

Wood Frame. JA4 Table 4.3.1 shows that a 2x6 wood-framed wall at 16-inches-on-center can achieve a U-factor of 0.048 with R-21 batt insulation in the cavity and R-5 exterior insulation.

Metal Frame. Metal-framed assemblies will require rigid insulation to meet the maximum U-factor criteria. U-factors for metal-framed walls are given in Reference Appendices, Joint Appendix JA4 Table 4.3.4 and can be calculated using Energy Commission-approved compliance software.

Calculating U-factors. U-factors can be calculated by building the construction assembly in Commission-approved compliance software, including the inside finish, sheathing, cavity insulation, and exterior finish.

Light and Heavy Mass Walls by Heat Capacity. The prescriptive requirements have separate criteria for mass walls. Mass walls may be light or heavy mass walls depending on their heat capacity. Light mass walls have at least 7.0 and less than 15.0 Btu/ft^2-°F, and heavy mass walls have at least 15.0 Btu/ft^2-°F in heat capacity. Light mass walls have prescriptive requirement of U-factor not exceeding 0.077 and with additional R 13 interior insulation on the interior surface of the mass wall for climate zones 1-15. The requirements are more stringent in climate zone 16, with a U-factor if 0.059 and with R 17 interior insulation.

For heavy mass walls, the U-factor requirements are 0.650 for climate zones 2-5 and 10, 0.690 for climate zones 6-9, 0.184 for climate zones 11, 14-15, 0.253 for climate zones 1 and 12, 0.211 for climate zone 13, and 0.160 for climate zone 16.

Mass walls with insulation applied to both the interior and exterior, such as insulated concrete forms (ICF), must meet the requirements for mass walls with interior insulation. Placement of insulation on mass walls will affect the thermal mass properties of a building. When the prescriptive compliance approach is used, the continuous insulation must be installed integral with or on the exterior or interior of the mass wall.

Calculating the U-Factor. To calculate the effective U-factor of a furred wall using the tables in Reference Appendices, Joint Appendix JA4:

1. Select a U-factor from JA4 Table 4.3.5 (Hollow Unit Masonry) or 4.3.6 (Solid Unit Masonry or Concrete) consistent with the type of wall.
2. Select the appropriate effective R-value for interior or exterior insulation layers from JA4 Table 4.3.14.
3. Use Equation 4-1, and the values selected, to calculate the U-factor of the construction assembly with the continuous insulation.
4. Compare the U-factor; it must be equal to or greater than the mass prescriptive U-factor from Energy Code Table 170.2-A to comply.

The U-factor of furred concrete or masonry walls can also be determined by building the construction assembly in Commission-approved compliance software.

Example 11-11: Wall Assembly Not Found in Reference Appendices, Joint Appendix JA4

Question 1

For a new wall, if 2 inches of medium–density, closed-cell spray polyurethane foam (ccSPF) is used in combination with R-13 batt insulation in the cavity of a 2x6 wood framed wall with 16” on center spacing, without continuous insulation added, what is the total U-factor for the wall assembly?

Answer 1

Medium-density ccSPF is given a default value of R-5.8 per inch, as per JA4 Table 4.1.7. When 2 inches of ccSPF is added to R-13 batt insulation, the total cavity insulation is rounded to R-25. The assembly U-factor was calculated to be 0.065 using Commission-approved compliance software.

Question 2

Does this assembly meet prescriptive compliance requirements in climate zones 6 and 7?

Answer 2

Yes. The assembly does meet the minimum mandatory wall insulation U-factor requirement of 0.071, as well as the prescriptive U-factor requirement of 0.065 in climate zones 6 and 7.

Question 3

How about in other climate zones?

Answer 3

No. The assembly does not meet the prescriptive compliance U-factor requirement of 0.051 in climate zones 1-5 and 8-16 for multifamily buildings. To meet the prescriptive requirement for those climate zones, other wall assemblies may be used, and/or advanced wall system (AWS) techniques may be used to reduce the framing factor. Alternatively, the project may be shown to comply with the Energy Code using the performance approach.

Question 4

How do I determine the U-factor value of metal framed wall assemblies?

Answer 4

Refer to Reference Appendices, Joint Appendix JA Tables 4.3.4 for U-factors correspond with metal frame walls with framing members 18 gauge or thinner, and to JA Table 4.3.3 for thicker framing members. The JA tables display the U-factor as a function of framing size, spacing, cavity and continuous insulation levels.

11.3.3.13 Raised-Floor Insulation

11.3.3.14 Raised-Floor Mandatory Requirements

§160.1(c)

Wood-framed floors over unconditioned space must have at least R-19 insulation installed between framing members, or the construction must have a U-factor of 0.037 or less. The equivalent U-factor is based on R-19 insulation in a 2x6, 16-inch on center wood-framed floor with a crawl space.

Other types of raised floors, except for concrete raised floors (concrete raised floors have a mandatory requirement of 0.269 maximum U-factor) must meet a maximum U-factor of 0.071. In all cases, some areas of the floor can have a U-factor greater than the requirement as long as other areas have a U-factor that is lower than the requirement and the area-weighted average U-factor is less than that described above.

Heated slab floors must meet special insulation requirements that are described in Section 11.1.9.5.

11.3.3.15 Raised-Floor Prescriptive Requirements

§170.2(a)5, Table 170.2-A

The prescriptive requirements differ for concrete raised floors and wood-framed floors. While the requirements for framed floors are the same in all climate zones, the requirements for (concrete) raised mass floors differ.

Wood Framed Raised Floors. The prescriptive U-factor requirement is the same as the mandatory level, at a maximum area-weighted U-factor of 0.037. Alternatively, the prescriptive requirement can be met by having a minimum of R-19 insulation installed between wood framing for framed raised floors in all climate zones.

Concrete Raised Floors. Concrete floors separating multifamily habitable space from a parking garage or other unconditioned spaces are considered exterior raised floors. Insulation requirements for concrete raised floors differ by climate zone, summarized in Table 11-10.

Table 11-10: Insulation Requirements for Concrete Raised Floors per Table 170.2-A

Climate Zone	1,2,11,13,14,16	12,15	3-10
U-Factor	< 0.092	< 0.138	< 0.269
R-Value of Continuous Insulation	> R-8	> R-4	No Req.

Source: California Energy Commission

Other Raised Floors, including metal framed floors. The prescriptive U-factor is 0.048 in climate zone 1, and 0.39 in climate zones 2 and 14-16. In climate zones 3-13, the prescriptive requirement matches the mandatory requirement at 0.071 U-factor.

Installation. Floor insulation should be installed in direct contact with. the subfloor so that there is no air space between the insulation and the floor. Support is needed to prevent the insulation from falling, sagging, or deteriorating. Options for support include netting stapled to the underside of floor joists, insulation hangers running perpendicular to the joists, or other suitable means. Insulation hangers should be spaced at 18 inches or less before rolling out the insulation. Insulation hangers are heavy wires up to 48 inches long with pointed ends, which provide positive wood penetration. Netting or mesh should be nailed or stapled to the underside of the joists. Floor insulation should not cover foundation vents.

11.3.3.16 Slab Insulation

A. Slab Insulation Mandatory Requirements

E. Slab Insulation Products

§110.8(g), Table 110.8-A

The mandatory requirements state that the insulation material must be suitable for the application. Insulation material in direct contact with soil, such as perimeter insulation, must have a water absorption rate no greater than 0.3 percent when tested in accordance with ASTM C272 Test Method A, 24-Hour Immersion, and a vapor permeance no greater than 2.0 perm/inch when tested in accordance with ASTM E96.

The insulation must be protected from physical and UV degradation by either installing a water-resistant protection board, extending sheet metal flashing below grade, choosing an insulation product that has a hard durable surface on one side, or by other suitable means.

The top of the insulation must be protected with a rigid material to prevent intrusion of insects into the building foundation.

A common location for the slab insulation is on the foundation perimeter. Insulation that extends downward to the top of the footing is acceptable. Otherwise, the insulation must extend downward from the level of the top of the slab, down 16 inches (40 cm) or to the frost line, whichever is greater.

For below-grade slabs, vertical insulation mustmust be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.

F. Heated Slab Floor Insulation

§110.8(g)

Material and installation specifications for heat slab floors mustmust adhere to the following:

1. Insulation values as shown in Table 110.8-A of the Energy Code
2. Protection from physical damage and UV light deterioration
3. Water absorption rate no greater than 0.3 percent (ASTM C272)
4. Water vapor permeance no greater than 2.0 perm/inch (ASTM E96)

See Section 11.5.6.4 for more details.

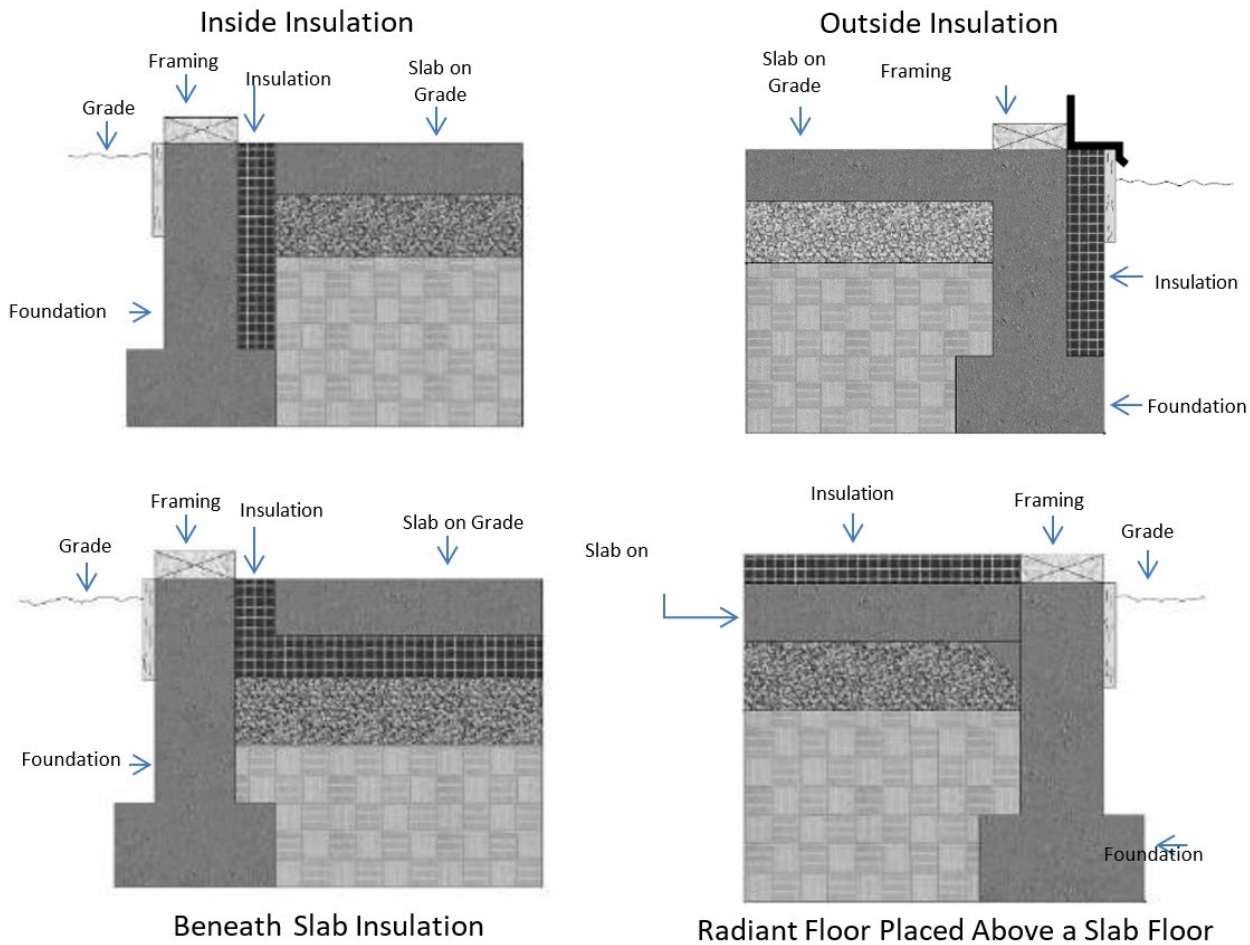
B. Slab Insulation Prescriptive Requirements

§170(a)5B, Table 170.2-A

Tables 170.2-A of the Energy Code require slab insulation for buildings up to three habitable stories but only for unheated slabs in climate zone 16. All heated slabs must meet mandatory insulation requirements in §110.8(g).

For unheated slabs in climate zone 16, a minimum of R-7 slab-edge insulation or a maximum U-factor of 0.58 must be achieved. The insulation must be installed to a minimum depth of 16 inches or to the bottom of the footing, whichever is less. The depth is measured from the top of the insulation, as near the top of slab as practical, to the bottom edge of the insulation.

Figure 11-6: Allowed Slab Edge Insulation Placement



Perimeter insulation is not required along the slab edge between conditioned space and the concrete slab of an attached unconditioned enclosed space such as a garage or covered patio.

11.3.3.17 Opaque Doors

170.2(a)4, Table 170.2-A

An opaque door is an installed swinging door separating conditioned space from outside or adjacent unconditioned space with less than 25 percent glazed area. A door that has 25 percent or more glazed area is a glazed door and is treated like a fenestration product. The requirement is applicable to doors for individual dwelling units and in common use area.

Opaque dwelling unit entry doors between conditioned and unconditioned space are prescriptively required to have an area-weighted average U-factor no greater than U-0.20, per Table 170.2-A. Swinging common use entry doors on separating conditioned and unconditioned space prescriptively require a 0.70 U-factor. Swinging doors between unconditioned and conditioned space that are required to have fire protection are exempt from the prescriptive requirement. As an example, this may include a fire protection door that separate a conditioned dwelling units and unconditioned corridor space. Non-swinging entry doors for common use areas must have a 1.45 U-factor requirement to meet prescriptive requirements, except in climate zones 1 and 16 where the U-factor requirement is 0.50. The U-factor must be rated in accordance with NFRC 100, or the applicable default U-factor defined in Reference Appendices, Joint Appendix JA4, Table 4.5.1 must be used.

At the field inspection, the field inspector verifies that the door U-factor meets the energy compliance values by checking the NFRC label sticker on the product. When manufacturers do not rate the thermal efficiencies by NFRC procedures, the Energy Commission default values must be used and documented on a temporary default label. Default U-factors values for various door types are shown in Table 11-11.

Table 11-11: Default U-Factors for Doors per JA Table 4.5.1

Description	**U-factor (Btu/ °F-ft²)**
Uninsulated single-layer metal swinging doors or non-swinging doors, including single-layer uninsulated access hatches and uninsulated smoke vents:	1.45
Uninsulated double-layer metal swinging doors or non-swinging doors, including double-layer uninsulated access hatches and uninsulated smoke vents:	0.70
Insulated metal swinging doors, including fire-rated doors, insulated access hatches, and insulated smoke vents:	0.50
Wood doors, minimum nominal thickness of 1-3/4 in. (44 mm), including panel doors with minimum panel thickness of 1-1/8 in. (28 mm), and solid core flush doors, and hollow core flush doors:	0.50
Any other wood door:	0.60
Uninsulated single layer metal roll up doors including fire rated door	1.45
Insulated single layer metal sectional doors, minimum insulation nominal thickness of 1-3/8 inch; expanded polystyrene (R-4 per inch).	0.179

Source: California Energy Commission

11.3.3.18 Vapor Retarder

§160.1(d)2

In climate zones 14 and 16, a continuous Class I or Class II vapor retarder, lapped or joint sealed, must be installed on the conditioned-space side of all insulation in all exterior walls, on the roof decks of vented attics with above-deck or below-deck air-permeable insulation, and in unvented attics with air-permeable insulation.

Buildings with unvented or controlled-ventilation crawl spaces in all climate zones must have a Class I or Class II vapor retarder placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with RA4.5.1.

Vapor retarder class is a measure of the ability of a material or assembly to limit the amount of moisture that passes through the material or assembly. Vapor retarder classes are defined in Section 202 of the California Building Code (CBC).

Testing for vapor retarder class is defined using the desiccant method of ASTM E96.

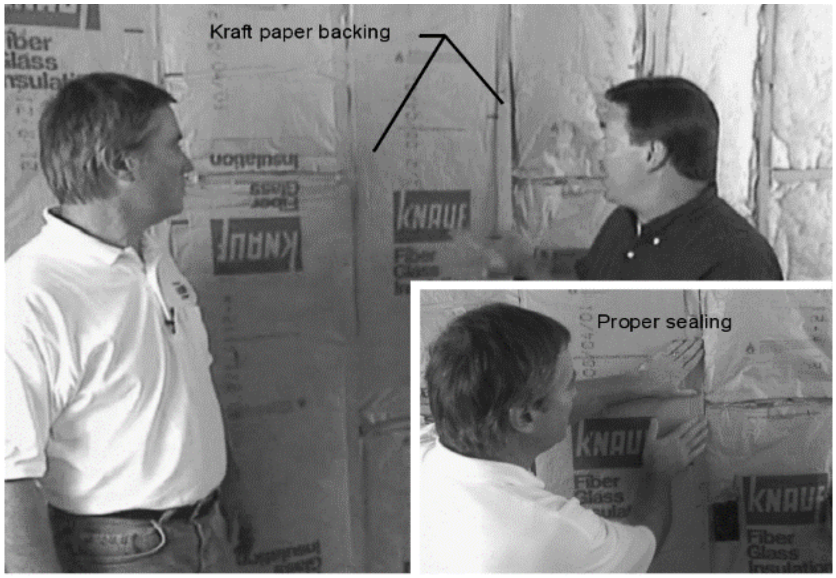
1. Class I: 0.1 perm or less
2. Class II: 0.1 < perm < 1.0 perm
3. Class III: 1.0 < perm < 10 perm

Following are common vapor retarder product types:

1. Foil and other facings on gypsum board can provide moisture resistance, and product literature shows conformance to ASTM E96.
2. Kraft paper facing on thermal batt insulation material is typically a Class II vapor retarder. Faced batts may have flanges for fastening to assembly framing. Fastening flanges may be face- or inset-stapled or not stapled at all, as the flanges provide no moisture control. Face stapling of flanged thermal batts helps ensure the insulation material is installed fully and properly within the framed cavity. Flangeless batts are also common and require no fastening as these materials maintain installation integrity through friction-fitting within the cavity of framed assemblies. In all cases, the insulation must be installed properly.
3. Interior painted surfaces may also serve as vapor retarders if the paint product has been tested and shown to comply with the vapor retarder requirements. The effectiveness of vapor retarder paint depends upon the installed thickness (in mils). These products often require more than one layer to achieve the tested perm rating, and care must be shown by the installer of the paint and for inspection by the building official.
4. Closed-cell spray polyurethane foam (ccSPF) products can provide Class I or Class II vapor retarder performance, depending on thickness.

For all types of vapor retarders, care should be taken to seal penetrations, such as electric outlets on exterior walls.

Figure 11-7: Typical Kraft-faced Vapor Retarder Facing



Source: California Energy Commission

11.3.3.19 Mandatory Air Sealing and Air Leakage

A. Joints and Other Openings

§110.7

See Section 3.2.3.1 for requirements related to infiltration and air leakage applicable across multifamily and nonresidential buildings.

B. Fireplaces, Decorative Gas Appliances, and Gas Logs

§160.1(f)

Closeable metal or glass doors must cover the entire firebox opening for fireplaces, decorative gas appliances, and gas logs in dwelling unit and common use areas. A combustion air intake no smaller than 6 square inches in area, with a tight-fitting damper or combustion-air control must also be installed. A flue damper with accessible control is also required.

11.3.3.20 Quality Insulation Installation (QII)

11.3.3.21 QII Prescriptive Requirements

§170.2(a)6, Table 170.2, RA 3.5

All insulation mustmust be installed according to manufacturer specifications, throughout the building. In multifamily buildings up to three habitable stories, a third-party HERS Rater is required to verify the integrity of the installed insulation. The installer mustmust provide evidence to the HERS Rater using compliance documentation that all insulation specified is installed to meet specified R-values and assembly U-factors.

To meet QII, two primary installation criteria must be adhered to, and they both must be field-verified by a HERS Rater. They include air sealing of the building enclosure (including walls, ceiling/roof, and floors), as well as proper installation of insulation. Refer to Reference Appendices, Residential Appendix RA3.5 for more details.

Many multifamily insulation installations have flaws that degrade thermal performance. Four problems are generally responsible for this degradation

1. There is an inadequate air barrier in the building envelope or holes and gaps within the air barrier system that allow air leakage.
2. Insulation is not in contact with the air barrier, creating air spaces that short-circuit the thermal break of the insulation.
3. The insulation has voids or gaps, resulting in portions of the construction assembly that are not properly insulated and, therefore, have less thermal resistance than other portions of the assembly.
4. The insulation is compressed, creating a gap near the air barrier and/or reducing the thickness of the insulation.

QII requires third-party HERS inspection to verify that an air barrier and insulation are installed correctly. Guidance for QII is provided in the Reference Appendices, Residential Appendix RA3.5. QII applies to framed and non-framed assemblies, including the following:

Table 11-12: Framed Assemblies vs. Non-Framed Assemblies

Framed Assemblies	Framed assemblies include wood and steel construction insulated with batts of mineral fiber, mineral and natural wool, or cellulose; loose-fill insulation of mineral fiber, mineral and natural wool, cellulose, or spray polyurethane foam (SPF). Rigid board insulation may be used on the exterior or interior of framed or non-framed assemblies.
Non-framed Assemblies	Nonframed assemblies include structural insulated panels (SIP), insulated concrete forms (ICF), and mass walls of masonry, concrete and concrete sandwich panels, log walls, and straw bale.

Source: California Energy Commission

Table 11-13 provides information on applicability and installation tips and examples for QII practices.

Table 11-13: Installer Tips for Implementing QII

QII Scheduling	In a multifamily building, it is typically necessary to coordinate and schedule multiple site visits to capture the totality of the both the air-sealing, and installed insulation portions of the QII inspection requirements. The HERS Rater must see the entirety of the envelope twice. Once to inspect air-sealed cavities before insulation is installed and again to inspect insulation before it is covered with drywall or other internal finishes. QII coordination and scheduling should account for the following: Staged construction timing between floors or building-zones for hanging insulation and covering it with internal finishes.

	Special interior finishes or structures that may close wall cavities off. For example – bathtubs, tiling, cabinets, and stairwells. Interior finishes being installed soon after insulation is installed. At some sites, contractors will hang drywall on the same day the insulation is installed. The HERS Rater must inspect the insulation in that small time window.
Applies to all Insulation	QII applies to the whole building (roof/ceilings, walls, and floors). Combinations of insulation types (hybrid systems) are allowed.
Air Barriers	An air barrier mustmust be installed for the entire envelope.
Insulated Headers	Headers mustmust meet one of the following criteria for QII: Two-member header with insulation in between. The header and insulation must fill the wall cavity. There are prefabricated products available that meet this assembly. Example: a 2x4 wall with two 2x nominal headers, or a 2x6 wall with a 4x nominal header and a 2x nominal header. Insulation is required to fill the wall cavity and must be installed between the headers. Two-member header, less than the wall width, with insulation on the interior face. The header and insulation must fill the wall cavity. Example: a 2x6 wall with two 2x nominal headers. Insulation is required to fill the wall cavity and must be installed to the interior face of the wall. Single-member header, less than the wall width, with insulation on the interior face. The header and insulation must fill the wall cavity. Example: a 2x4 wall with a 3-1/8-inch-wide header, or 2x6 wall with a 4x nominal header. Insulation is required to fill the wall cavity and must be installed to the interior face of the wall. Single-member header, same width as wall. The header must fill the wall cavity. Example: a 2x4 wall with a 4x nominal header or a 2x6 wall with a 6x nominal header. No additional insulation is required because the header fills the cavity, provided that the entire wall has at least R-2 insulation.
Panel Box Headers	Wood structural panel box headers may also be used as load-bearing headers in exterior wall construction, when built in accordance with 2019 California Residential Code (CRC) Figure R602.7.3 and Table R602.7.3.
Structural Bracing, Tie-Downs, Steel Structural Framing	Metal bracing, tie-downs, or steel structural framing can be used to connect to wood framing for structural or seismic purposes, and comply with QII if: Metal bracing, tie-downs, or steel structural framing is identified on the structural plans. Insulation is installed in a manner that minimizes the thermal bridging through the structural framing assembly. Insulation fills the entire cavity and/or adheres to all six sides and ends of structural assemblies that separate conditioned from unconditioned space. The structural portions of assemblies are airtight.

Source: California Energy Commission

A. Air Barrier

RA 3.5

An air barrier mustmust be installed enclosing the entire building. The air barrier must be installed in a continuous manner across all components of framed and non-framed envelope assemblies. The installer mustmust provide evidence with compliance documentation that the air barrier system meets one or more of the air barrier requirements. More detailed explanation is provided in Reference Appendices, Residential Appendix RA3.5. Documentation for the air barrier includes product data sheets and manufacturer specifications and installation guidelines.

As part of QII for multifamily buildings up to three habitable stories, a third-party HERS Rater is required to verify that the air barrier has been installed properly and is integral with the insulation being used throughout the building.

B. QII Performance Requirements

When using the performance approach for a multifamily building up to three habitable stories, QII may be traded off with other efficiency features. However, the compliance modeling software assumes QII and full insulation effectiveness in the standard design. The compliance modeling software automatically reduces the effectiveness of insulation for the proposed design in projects that do not pursue QII, with the assumption that QII results in a properly installed system. Poor installation practices compromise the effectiveness of the air barrier and insulation products and results in worse envelope thermal performance than assumed in the standard design.

Similar increases in heat loss and heat gain are experienced for roof/ceilings where construction and installation flaws are present. The reduction in effectiveness reflects standard industry installation practices and allows for full insulation credit to be taken for HERS verified quality insulation installation.

QII is not a compliance option for multifamily buildings with four or more habitable stories.

11.3.3.22 Advanced Opaque Envelope Options Requiring the Performance Approach

The performance approach offers increased flexibility and compliance credits for certain assemblies. For buildings up to three habitable stories this often includes compliance credits requiring HERS verification. The proposed design used under the performance approach is compared to the standard design, which is determined by the prescriptive requirements. This section describes several envelope assemblies and techniques that require use of the performance approach. See the Residential Compliance Manual Section 3.6 for extensive detailed descriptions and illustrations.

Advanced Building Practices. Common strategies for exceeding the minimum energy performance level set by the 2022 Energy Code include:

- Higher insulation levels.
- More efficient fenestration.
- Reduced building infiltration.
- Use of cool roof products.
- Better framing techniques (such as the use of raised-heel trusses that accommodate more insulation).
- Reduced thermal bridging across framing members.
- Use of non-framed assemblies or panelized systems (such as SIPs and ICFs).
- More efficient heating, cooling, and water-heating equipment.

11.3.3.23 Alternative Construction Assemblies

This section describes several advanced construction assemblies. These three assemblies are included in the Reference Appendices, Joint Appendix JA4 U-factor tables for use in the compliance software.

Structural Foam Wall Systems The high performance structural foam wall assembly is an advanced assembly system that consists of closed cell spray polyurethane foam (ccSPF) placed in the cavity bonded to wood framing and continuous rigid board insulation on the exterior of the frame. The bond that occurs between the ccSPF, the framing, and the continuous rigid insulation can provide code-compliant wind and seismic structural load resistance without the use of OSB sheathing

A builder can configure the thicknesses of the cavity ccSPF, rigid insulation, and alternative cavity insulation to attain U-factors of 0.050 or better in 2x4 at 24” on center assembly. The structural foam wall assembly can be combined with advanced framing techniques to increase energy and resource efficiency while reducing material and labor costs.

Structural Insulated Panels (SIPs) Structural insulated panels (SIPS) are a non-framed advanced construction system that consists of rigid foam insulation sandwiched between two sheets of board. The board can be sheet metal, plywood, cement, or oriented strand board (OSB), and the foam can be expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane (PUR), or polyisocyanurate (ISO) foam. Little or no structural framing penetrates the insulation layer.

SIPs combine several components of conventional building, such as studs and joists, insulation, vapor barrier, and air barrier. They can be used for many different applications, such as exterior walls, roofs, floors, and foundation systems. Reference Appendices, Joint Appendix JA4 Table 4.3.2 has U-factors for SIPS wall assemblies, and JA4 Table 4.4.3 has U-factors for SIPS floor constructions. U-factors used for compliance must be taken from these tables or by using Commission-approved compliance software.

Insulating Concrete Forms (ICF) Insulating concrete forms (ICFs) are a system of interlocking formwork for concrete that stays in place as permanent building insulation and can be used for cast-in-place reinforced above- and below-grade concrete walls, floors, and roofs. The insulating panels are made from expanded polystyrene (EPS) and extruded polystyrene (XPS) rigid insulation boards, polyurethane (PUR), composites of cement and EPS, and composites of cement and shredded wood fiber. ICF wall assemblies provide three energy efficiency benefits:

1. Continuous rigid insulation on both sides of a high-mass core
2. Elimination of thermal bridging from wood framing components
3. A high degree of airtightness inherent to this method of construction

The thermal aspects of ICFs are represented in Reference Appendices, Joint Appendix JA4 Table 4.3.13.

B. Advanced Wall Framing

Advanced wall systems (AWS), or advanced framing, refer to a set of framing techniques and practices that minimize the amount of wood necessary to build a structurally sound, safe, durable, and energy-efficient building. AWS improves energy and resource efficiency while reducing first costs.

Reducing the amount of framing (wood or metal) in exterior walls improves energy efficiency with more insulation, a reduced framing factor and reduced thermal bridging. The standard framing factor for a wood-framed 2x4 wall at 16” on center is 25 percent. When AWS is used, the framing factor is reduced to 17 percent, reflecting improved energy performance.

Double and Staggered Wall Assemblies. Double-wall and staggered-wall systems were developed to better accommodate electrical and plumbing systems, allow higher levels of insulation, and provide greater sound reduction. The advantages of these types of wall systems are:

1. Smaller dimensional lumber can be used.
2. It is easier to install insulation properly.
3. It eliminates thermal bridging through the framing.
4. It reduces sound transmission through the wall.

11.3.3.24 Roofs

Roof techniques and assemblies required to use the performance approach include:

- Unvented attics
- Above-deck insulation
- Insulated roof tiles
- Raised heel, extension truss, or energy truss
- Nail base insulation panels

11.3.3.25 Unvented Attics

Attic ventilation is the traditional way of controlling temperature and moisture in an attic. In an unvented attic assembly, insulation is applied directly at the roofline of the building, either above or below the structural roof rafter. The roof system becomes part of the insulated building enclosure. The thermal boundary of the building results in an unvented attic space between the ceiling gypsum board and the insulated roof above.

Gable Ends in Unvented Attics. In unvented attics, where insulation is applied directly to the underside of the roof deck, framing for gable ends that separate the unvented attic from the exterior or unconditioned space should be insulated to meet or exceed the wall R-value of the adjacent exterior wall construction. The side of air-permeable insulation exposed to the unconditioned attic space should be completely covered with a continuous air barrier.

11.3.3.26 Above-Deck Insulation

Above-deck insulation requires insulation above the roof rafters, directly in contact with the roof deck to improve thermal integrity of the roof system. An air space between the roofing and the roof deck provides additional benefit. Above-deck insulation can be implemented with either asphalt shingles or clay/concrete tiles. Details for above-deck insulation details differ depending on the type of roof tiles. Refer to the Residential Compliance Manual Section 3.6 for detailed descriptions.

11.3.3.27 Insulated Roof Tiles (IRT)

Insulated roof tile (IRT) can improve the thermal performance of the roof assembly and lower attic temperatures. IRT combines concrete or clay tiles with insulation as a packaged product. Most of the increase in R-value is due to the integration of insulation into the roofing product itself. Additional thermal performance can be gained by combining IRT with rigid foam insulation inserts. These tiles are lighter than typical roof tiles and have better thermal performance than traditional tiles due to the insulating core. IRT can reduce radiant losses and maintain warmer roof deck temperatures, thereby reducing the potential for condensation.

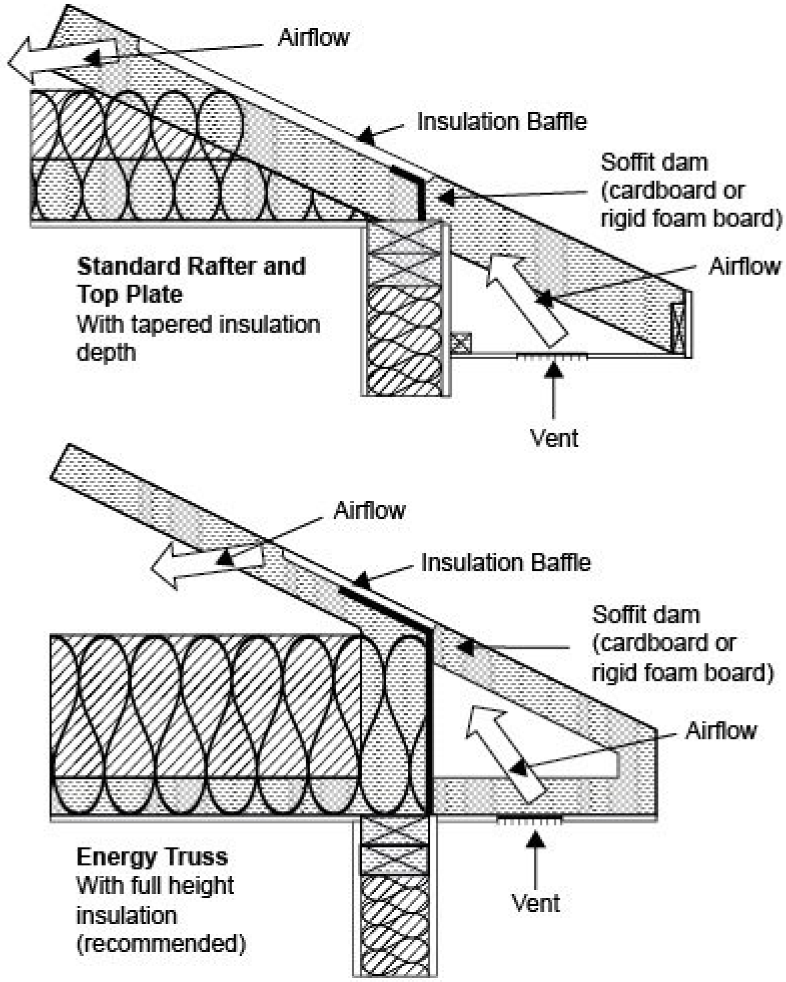
11.3.3.28 Raised Heel, Extension Truss, or Energy Truss

Raised heel or extension trusses allow full depth, uncompressed insulation at the ceiling to continue to the ceiling edge where the wall and ceiling meet. The roof truss is assembled with an additional vertical wood framed section at the point where the truss bears on the wall. The vertical section raises the top chord and provides increased space that can be filled with insulation. See Figure 11-9 for details of a raised heel truss. Benefits of this strategy include:

- Realizing the full benefit of ceiling insulation.
- Providing more space for air handler and duct systems if located in the attic.

Similar construction methods include framing with a rafter on a raised top plate or using spray foam or rigid foam at the edge.

Figure 11-8: Standard Truss vs. Raised Heel Energy Truss



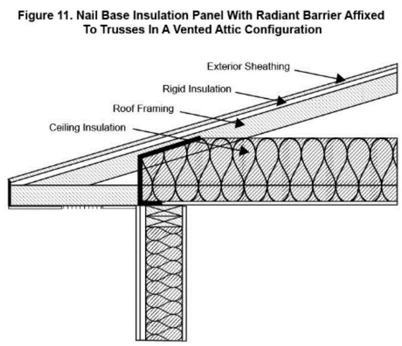
Source: California Energy Commission

11.3.3.29

11.3.3.30 Nail Base Insulation Panel

The nail base insulation panel is a deck insulation strategy that consists of exterior-facing OSB, or other structural sheathing laminated to continuous rigid insulation, which is fastened directly to roof framing (Figure **11-10**). This saves the time and expense of installing a structural sheathing layer above and below the rigid insulation. The nail base insulation panel creates a nailing surface for attaching roof cladding. Suitable for vented and unvented attic assemblies, the exposed underside of the rigid insulation has a facer that provides a radiant barrier, as well as ignition/thermal barrier protection as required by code.

Figure 11-9. Nail Base Insulation Panel with Radiant Barrier Affixed to Trusses in A Vented Attic Configuration



11.3.3.31 Thermal Mass

Thermal mass consists of exposed mass walls, tiled or exposed concrete floors and other heavy elements within the building envelope that can help stabilize indoor temperatures.

Mass walls typically fall into two categories:

- **Masonry.** Masonry includes solid or hollow-core clay and concrete units. Concrete masonry units (CMU) are made from a mixture of Portland cement and aggregates under controlled conditions. Other masonry unit types include cast stone and calcium silicate units.
- **Concrete and concrete sandwich panels.** Concrete and concrete sandwich panels typically use a precast form by casting concrete in a reusable mold or "form" that is then cured in a controlled environment, transported to the construction site, and lifted into place. Precast stone is distinguished from precast concrete by using a fine aggregate in the mixture, giving the appearance of naturally occurring rock or stone.

When the performance method is used, credit is offered for increasing thermal mass in buildings. This procedure is automated in Energy Commission-approved compliance software.

11.3.4 Fenestration

The size, orientation, and types of fenestration products, such as windows, glazed doors, dynamic glazing, window films, and skylights, have a significant impact on energy use and heating and cooling loads in the building and can dramatically affect the overall energy performance of a building.

Any door that is 25 percent or greater glass is considered a glazed door and must comply with the mandatory requirements and other requirements applicable to a fenestration product. Vertical fenestration in demising walls (between conditioned spaces) are required to comply with the area-weighted average U-factor requirement in Table 170.2-A.

Several factors affect window performance. For fenestration with NFRC ratings, the following performance features are accounted for in the U-factor and SHGC ratings:

Frame materials, design, and configuration (including cross-sectional characteristics). Fenestration can be framed in many materials. The most common include vinyl, wood, fiberglass, aluminum, or composites of these materials. Frames made of low-conductance materials like wood, vinyl, and fiberglass are better insulators than metal. Some aluminum-framed units have thermal breaks that reduce the conductive heat transfer through the framing element compared with similar units having no such conductive thermal break.

Number of panes of glazing, low-emissivity (low-e) coatings, tints, fill gases, cavity dimensions, and spacer construction. Windows compliant with the prescriptive requirements are likely to have at least double-glazing with a low-emissivity (low-e) coating and argon gas fill with an improved spacer. The choice of low-e coating is particularly important as cooling climates will generally benefit from a low SHGC coating, while heating climates may benefit from a high SHGC coating. Adding glazing layers such as triple glazing and low-emissivity coatings such as those facing the conditioned space are two likely improvements.

Window components, such as tints and coatings, reduce visual transmittance (VT), reducing light to interior spaces and increasing energy for interior lighting. VT requirements for multifamily buildings four or more habitable stories allow for daylighting and daylighting controls on interior light fixtures.

11.3.4.1 Fenestration Types

Section 3.3.1 includes fenestration and category definitions applicable across nonresidential and multifamily buildings. Prescriptive multifamily fenestration requirements depend on which of the following window types are installed.

- **Curtainwall, window wall, or storefront** windows consist of metalized or glass panels often hung outside structural framing to create exterior wall elements around fenestration and between floors.
- **NAFS Performance Class AW (architectural windows)** adhere to industry standard – AAMA/ WDMA/ CSA 101/ I.S.2/ A440 NAFS-2017 North American Fenestration Standard/ Specification, which includes testing requirements for fenestration products based on air leakage resistance, water penetration resistance, uniform load resistance and forced-entry resistance. The Performance Classes are designated R, LC, CW, and AW in order of performance. Higher rated products typically rely on metal window framing materials which lead to high thermal bridging in the window frame and thus higher U-factors. Windows must be certified as NAFS rated to qualify for the category.

  Performance Class AW windows are significantly more expensive than lower-rated products and are unlikely to be specified unless necessary. The architect calculates the building’s wind loads to determine if Class AW windows are needed. There is no specific code that regulates this decision. It is ultimately at the discretion of the architect and building owner.

- **All other fenestration** includes operable windows, punched fixed windows, glass doors, and skylights that do not qualify as NAFS Performance Class AW.

11.3.4.2 Fenestration Mandatory Requirements

§110.6(a), Table 110.6-A, 160.1(e)

Mandatory requirements for fenestration products, labeling, and air leakage for multifamily and nonresidential buildings are covered in Section 3.3.2.

The area-weighted U-factor of all fenestration, including skylights, may not exceed 0.58.

Exception for Greenhouse/Garden Windows. Compared to other fenestration products, the NFRC-rated U-factor for greenhouse windows are comparatively high. Section 160.1(e)1 includes an exception from the U-factor requirement for dual-glazed greenhouse or garden windows that total up to 30 ft² of rough opening area per dwelling unit.

11.3.4.3 Fenestration Prescriptive Requirements

§170.2(a)3A, Table 170.2-A

11.3.4.4 Fenestration Area

Multifamily buildings have three prescriptive fenestration area limitations. All three must be met for prescriptive compliance.

1. Total combined vertical fenestration and skylight area may not exceed 20 percent of the conditioned floor area (CFA)
2. Total vertical fenestration may not exceed 40 percent of the gross exterior wall area.
3. Total skylight area may not exceed 5 percent of the gross exterior roof area.

11.3.4.5 Fenestration Properties

Prescriptive fenestration requirements, for vertical and skylight fenestration, for multifamily buildings refer to Table 170.2-A. The maximum fenestration U-factor and maximum relative solar heat gain coefficient (RSHGC), and minimum visible transmittance (VTT depend on window type and climate zone. The required RSHGC additionally depends on whether a multifamily building is three or fewer or four or more habitable stories. Only buildings with four or more habitable stories are subject to VT requirements.

Relative solar heat gain coefficient (RSHGC) allows for an external shading correction from exterior shading devices and overhangs. A fenestration product with an SHGC greater than prescriptively required may qualify if an opaque exterior shading device or overhang is used and the combined area-weighted average complies with the prescriptive requirements. Balconies that extend above glazing are common overhangs in multifamily buildings. See Section 3.3.3 for more information about SHGC and Overhang Factor.

For credit, exterior shading devices must be permanently attached as opposed to being attached using clips, hooks, latches, snaps, or ties.

The window property requirements for each fenestration type are as follows.

Curtainwall or storefront fenestration has a maximum U-factor of 0.38 in Climate Zones 1 and 16 and 0.41 in Climate Zones 2 through 15. For multifamily buildings with four or more habitable stories, the maximum RSHGC is 0.35 in Climate Zone 1, 0.26 in Climate Zones 2 through 13 and 15, and 0.25 in Climate Zones 14 and 16. Multifamily buildings up to three habitable stories in Climate Zones 1, 3, 5, and 16 have no RSHGC requirements. Minimum VT is 0.46 across all climate zones for buildings with four or more habitable stories.

Performance Class AW rated fenestration has a maximum U-factor of 0.38 in Climate Zones 1 and 16 and 0.40 in Climate Zones 2 through 15. The maximum RSHGC in Climate Zone 1 is 0.35 and 0.24 in all other climate zones. Multifamily buildings up to three habitable stories in Climate Zones 1, 3, 5, and 16 have no RSHGC requirements. Minimum VT is 0.37 across all climate zones for buildings with four or more habitable stories.

All other fenestration has a maximum U-factor of 0.30 in Climate Zones 1 through 5 and 8 through 16 and 0.34 in Climate Zones 6 and 7. The maximum RSHGC is 0.23 for buildings in Climate Zones 2, 4, and 6 through 15. Multifamily buildings up to three habitable stories in Climate Zones 1, 3, 5, and 16 have no RSHGC requirements. There is no VT requirement for fenestration in the "all other" category.

The requirements apply to fenestration products without consideration of insect screens or interior shading devices. With some exceptions, some fenestration products may exceed the prescriptive requirement as long as the U-factor and RSHGC of windows, glazed doors, and skylights can be area weight-averaged together to meet the prescriptive requirement using the certificate of compliance document in Appendix A of this manual.

See Table 170.2-A for summarizes of climate zone-specific prescriptive requirements by fenestration type.

Exceptions to the prescriptive fenestration requirements include:

- **Glazed Doors.** Each new dwelling unit may have up to 3 ft2 of glass in a door that do not meet the prescriptive U-factor and RSHGC requirements.
- **Skylights.** Each new dwelling unit with roof area may have up to 16 ft2 of skylight area that does not meet the prescriptive U-factor and SHGC requirements. The exempted skylight must have a maximum 0.55 U-factor and a maximum SHGC of 0.30. See Exception 2 of §170.2(a)3Bii.
- **Chromogenic Glazing.** If a multifamily building includes chromogenic type glazing that is automatically controlled, the lowest U-factor and lowest SHGC must meet the prescriptive requirements. This type of product cannot be weight

averaged with nonchromogenic products as per Exception to Section 170.2(a)3Bii and Section 170.2(a)3Biii.

- **Bay Windows.** Bay windows with no rating for the entire unit (where there are multiple windows that make up the bay) and with factory-installed or field-installed insulation must comply accounting for the performance characteristics of each component separately.

First story display perimeters and where overhangs are prohibited by code can have a maximum RSGHC of 0.56 and do not need to meet the RSHGC requirements in Table 170.2-A. U-factor and VT requirements of Table 170.2-A apply.

11.3.4.6 Fenestration in the Performance Approach

§170.1

The performance approach offers increased flexibility as well as compliance credits for high performance fenestration. The compliance software compares whole building energy use, as calculated with the proposed window properties, area, and orientation, to whole building energy use as calculated with prescriptive U-factor and RSHGC values. The following are fenestration strategies for improved energy performance.

A. Fenestration Area and Orientation

The performance approach accounts for fenestration area and orientation, which impact energy use. The standard design window orientations match the proposed design. While there is no compliance credit for window placement across orientations, window placement to avoid solar heat gain will result in lower cooling loads and can lower the overall energy budget in the building and therefore reduce the size of the solar PV system required to offset energy use.

For buildings with glazing areas less than or equal to 20 percent of the conditioned floor area (CFA) and less than or equal to 40 percent of the exterior wall area, the standard design fenestration for a newly constructed building is modeled with the same glazing area as the proposed building. For buildings with more than 20 percent of the CFA or more than 40 percent exterior wall area, the standard design glass area is limited to the lower of 20 percent of the CFA or 40 percent of the exterior wall area. The software reduces fenestration area proportionate to total fenestration area across each orientation in the standard design.

B. Improved Fenestration Performance

The fenestration weighted average U-factor and RSHGC in the standard design for newly constructed buildings is defined in Table 170.2-A, dependent on window type and climate zone. High-performance fenestration that performs better than the prescriptive requirements provide credit through the performance method. The magnitude of the effect of a lower U-factor will vary by climate zone. In mild coastal climates, the benefit from reducing fenestration U-factor will be smaller than in more extreme climates. In hot climates, choosing a window with an SHGC lower than prescriptively required will reduce the cooling loads compared to the standard design. Window film and dynamic glazing are also two options for improved window performance. Section 3.3.3.2 incudes more information on these options.

C. Fixed Permanent Shading Devices

Overhangs or side fins that are attached to the building and shading from the building itself can be accounted for in the performance approach and impact building heating and cooling loads. See Section 3.5.1.4 for more information on modeling overhangs and vertical shading fins.

Example 11-12: Multiple Window Types in a Project

Question

My building will have a combination of window types, including fixed, operable, wood, metal, and so forth, some of which are field-fabricated. What are the options for showing compliance with the standards?

Answer

All windows must meet the mandatory requirements of §110.6 and §110.7 and the mandatory maximum area-weighted average U-factor of 0.58 from §160.1(e)1, unless exempted. For field-fabricated windows, you must select U-factors and SHGC values from the default tables (Table 110.6-A and Table 110.6-B of the Energy Code). Windows that are not field-fabricated must be labeled with NFRC-certified or default efficiencies. Few fenestration products in the default tables meet the mandatory maximum U-factor of 0.58 on their own.

If the area-weighted average U-factors or SHGC values do not comply with the prescriptive requirements in Table 170.2-A, the performance method must be used. To simplify data entry into the compliance software, you may choose the U-factor from Table 110.6-A of the Energy Code that is the highest of any of the windows planned to be installed and use this for all windows for compliance. However, you must use the appropriate SHGC from Table 110.6-B for each window type being installed.

11.3.5 Daylighting

Enclosed conditioned and unconditioned spaces greater than 5,000 ft^2 and with ceiling heights exceeding 15 feet must meet daylighting requirements as described in Section 3.3.4.2E.

11.3.6 Additions and Alterations

11.3.6.1 Additions

Additions to all multifamily building dwelling units and common use areas mustmust meet the mandatory envelope requirements for newly constructed buildings including:

- Ceiling and roof insulation (see Section 11.1.8.20)
- Wall insulation (See Section 11.1.9.30)
- Floor insulation (See Section 11.3.1.6A and 11.1.9.5A)

- Vapor retarder (See Section 11.1.9.7)
- Fireplace, decorative gas appliances, and gas log provisions (See Section 11.1.9.8)
- Fenestration U-factor of 0.58 (See Section 11.1.10.2)

Prescriptive requirements for additions match those for newly constructed buildings (See Sections 11.1.8 and 11.1.10) with some modifications that depend on the conditioned floor area of the addition.

For additions greater than 700 square feet (ft^2):

- Fenestration area must not exceed 175 square feet or 20 percent of the addition floor area.
- Extensions of existing framed walls may retain the dimensions of the existing wall. In these cases, R-15 insulation must fill cavities in 2x4 stud walls and R-21 in 2x6 stud walls.
- If siding is not removed during construction, no continuous insulation is required on existing walls. In these cases, R-15 insulation must fill cavities in 2x4 stud walls and R-21 in 2x6 stud walls.
- The air sealing elements of QII are not required in cases where unconditioned space is being converted to conditioned space when the existing air barrier is not being removed or replaced.
- Additions that increase the area of the roof by 2,000 square feet or less are exempt from the solar ready requirements of Section 160.8.

For additions 700 square feet or less:

- Overall roof and ceiling assemblies are required to achieve an overall U-factor of 0.025 or less in Climate Zones 1,2,4, and 8-16 and a U-factor of 0.031 in Climate Zones 3, 5, 6, and 7. A wood framed assembly would need R-38 insulation to achieve a 0.025 U-factor and R-30 insulation for a 0.031 U-factor.
- Radiant barrier is required in buildings up to three habitable stories in Climate Zones 2-15.
- Extensions of existing framed walls may retain the dimensions of the existing wall. In these cases, R-15 insulation must fill cavities in 2x4 stud walls and R-21 in 2x6 stud walls.
- Fenestration U-factor, RSHGC, and VT must meet requirements of Table 180.2-B (See Section 11.1.12.2)
- QII is not required.
- Additions up to 300 sq. ft. are exempt from the prescriptive roof product requirements.

11.3.6.2 Alterations

11.3.6.3 Roof Alterations

Roofs with more than 50 percent of the roof area or 2,000 square feet of roof (whichever is less) being recovered or recoated are required to have minimum aged solar reflectance and thermal emittance, or solar reflectance index (SRI), determined by slope and climate zone. Low-sloped roofs in Climate Zones 2, 4, and 6 through 15 mustmust have a minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75, or a minimum SRI of 75. This requirement may alternatively be met through roof deck insulation, as summarized by Climate Zone in Table 11-14. Climate Zones 1, 3, and 16 do not have cool roof requirements.

Table 11-14: Roof/Ceiling Insulation Tradeoff for Low-Sloped Aged Solar Reflectance (Table 180.2-A)

Minimum Aged Solar Reflectance	Roof Deck Continuous Insulation R-value (Climate Zones 6-7)	Roof Deck Continuous Insulation R-value (Climate Zones 2, 4, 8-15)
0.60	2	16
0.55	4	18
0.50	6	20
0.45	8	22
No requirement	10	24

Source: California Energy Commission

Steep-sloped roofs in Climate Zones 4 and 8 through 15 require a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16. Equivalence may be demonstrated through:

- A 0.025 U-factor ceiling assembly; or
- An attic radiant barrier, not installed directly above spaced sheathing; or
- R-2 or greater insulation above or below the roof deck; or
- No ducts in the attic in Climate Zones 2, 4, 9, 10, 12, or 14.

Roof area covered by building integrated photovoltaic panels or building integrated solar thermal panels is not required to meet the minimum requirements for aged solar reflectance and thermal emittance, or SRI. Roof constructions with a weight of at least 25lb/ft^2 are also exempt from the aged solar reflectance and thermal emittance or SRI requirement.

In Climate Zones 1,2,4, and 8 through 16, low-sloped roofs mustmust additionally be insulated to R-14 continuous insulation or 0.039 U-factor. Roofs with new R-10 insulation above deck are exempt from this requirement.

Vented attics in Climate Zones 1-4 and 8-16 are required to have insulation installed to a weighted U-factor or 0.020, or R-49 ceiling insulation. Buildings with existing R-19 or greater insulation at the ceiling level in Climate Zones 1, 3, 4, and 9 are exempt from this requirement.

Vented attics in Climate Zones 2 and 11-16 are required to air seal accessible areas of the ceiling plane between the attic and conditioned space per §110.7. Dwelling units with existing R-19 or greater insulation at the ceiling level are exempt from this requirement. Dwelling units with atmospherically vented space or water heating appliances within the pressure boundary of the dwelling unit are also exempt.

In vented attics in Climate Zones 1-4 and 8-16, recessed downlight luminaires in the ceiling mustmust be covered with insulation to the same depth as the rest of the ceiling. Luminaires not rated for insulation contact must be replaced or fitted with a fire-proof cover that allows for insulation to be installed directly over the cover. Dwelling units with existing R-19 or greater insulation at the ceiling level are exempt from this requirement in Climate Zones 1-4 and 8-10.

Attic ventilation must comply with California Building Code (CBC) requirements.

Exemptions for the roof insulation requirements for ventilated attics include:

- Dwelling units with at least R-38 existing insulation installed at the ceiling level
- Dwelling units where the alteration would directly cause the disturbance of asbestos
- Dwelling units with knob and tube wiring located in the attic
- Where the accessible space in the attic is not large enough to accommodate the required R-value, the entire accessible space mustmust be filled with insulation
- Where the attic space above the altered dwelling unit is shared with other dwelling units and the requirements are not triggered for the other dwelling units.

11.3.6.4 Wall Alterations

Walls separating conditioned space from unconditioned space, with the exception of mass walls, must be insulated to a mandatory minimum R-value between framing members or area-weighted U-factor, dependent on the assembly type:

- Metal building walls: R-13 insulation or 0.113 assembly U-factor
- Metal framed walls: R-13 insulation or 0.217 assembly U-factor
- Wood framed and other walls: R-11 insulation or 0.110 assembly U-factor
- Spandrel panel and curtain walls: R-4 insulation or 0.280 assembly U-factor

11.3.6.5 Floor Alterations

Floors separating conditioned space from unconditioned space must be insulated to a mandatory minimum R-value or area-weighted U-factor, dependent on the assembly type:

- Raised framed floors: R-11 insulation or 0.071 U-factor
- Raised mass floors: R-6 insulation or 0.111 U-factor

11.3.6.6 Fenestration Alterations

The area-weighted U-factor of all fenestration, including skylights, may not exceed the mandatory maximum of 0.58.

Alterations that replace existing fenestration of the same total area can meet prescriptive requirements by meeting the maximum U-factor, RSHGC, ad VT requirements of Table 180.2-B for each window replaced or an area weighted U-factor and RSHGC across all replaced windows from Table 170.2-A. Where 150 square feet or less of the building's vertical fenestration is replaced, the building is exempt from the RSHGC and VT requirements.

Alterations that add fenestration are required to meet the total fenestration area requirements and the U-factor, RSHGC, and VT requirements of §170.2(a)3 and Table 170.2-A. Alterations that add vertical fenestration area of up to 50 ft^2 to the building are exempt from this requirement. Alterations that add skylight area up to 16 ft^2 to the building are exempt from fenestration area and Table 170.2-A requirements but may meet not exceed a U-factor of 0.55 or an RSHGC of 0.30.

See Section 11.1.10.3 for Table 170.2-A requirements. See Table 180.2-B for Altered Fenestration Maximum U-Factor and Maximum SHGC.

11.3.6.7 Door Alterations

Alterations that add exterior door area mustmust meet the U-factor requirement of §170.2(a)4 (See Section 11.1.9.6).

11.3.7 Code in Practice

11.3.7.1 Garden Style Multifamily Case Study

The Garden Style Multifamily Case Study considers a new two-story garden style multifamily building in Burbank, California (Climate Zone (CZ) 9). This is a sample project created for training purposes, and it consists of 7,216 ft^2 of conditioned floor area with eight dwelling units and no common use areas. The case study tables in this chapter compare the proposed building envelope features to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Figure 10: Garden Style Multifamily: South (Front) and West (Left) Elevations

Figure 11: Garden Style Multifamily: North (Rear) and East (Right) Elevations

Figure 12: Garden Style Multifamily: 1st Floor, 1-Bedroom Apartment

Table 11-15: Garden Style Multifamily Case Study Compared to Mandatory and Prescriptive Envelope Requirements (Climate Zone 9) Total Conditioned Floor Area and Fenestration

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Multifamily Building	New two-story garden style multifamily building, eight dwelling units, no common use areas, Burbank, CA	Sections 110.6, 110.7, 110.8, 160.1	Section 170.2(a), Table 170.2-A New multifamily building less than or equal to three habitable stories, Climate Zone (CZ) 9	Case study Mandatory and Prescriptive compliance rated for each feature below as “Yes” (complies), “No” (does not comply) or “N/A” (not applicable). If “No”, see compliance options provided.
Total Conditioned Floor Area (CFA)	1st Floor: (122′ x 30′) – 4(26 ft²) = 3,556 ft² 2nd Floor: (122′ x 30′) = 3660 ft² Total = 7,216 ft²	7,216 ft²	7,216 ft²	
Fenestration	Manufactured NFRC-rated dual pane low-e glass, vinyl frame, operable, no shading			
U-factor	NFRC-rated U-factor = 0.30	All CZ: ≤ 0.58	CZ 9: ≤ 0.30	Mandatory: Yes Prescriptive: Yes
RSHGC	NFRC-rated RSHGC = 0.23	N/A	CZ 9: ≤ 0.23	Mandatory: N/A Prescriptive: Yes
Total Fenestration Area	N: 2(150) = 300 ft² E: 2(25) = 50 ft² S: 2(150) = 300 ft² W: 2(25) = 50 ft² Total = 700 ft² Window-Wall Ratio (WWR): 700 / 4,898 = 14.3% Window-Floor Ratio	N/A	*The smaller of* 40% WWR: 0.40 x 4,898 ft² = 1,959 ft² *and* 20% WFR: 0.20 x 7,216 ft² = 1,443 ft² Total ≤ 1,443 ft²	Mandatory: N/A Prescriptive: Yes

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
	(WFR): 700 / 7,216 = 9.7%			

Table 11-16: Roof, Wall, and Floor, plus Verifications Case Studies

Roof and Ceiling: Insulation, Radiant Barrier and Roofing

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Roofing: Aged Solar Reflectance	Steep-sloped (≥2:12), CRRC-rated Aged Solar Reflectance = 0.20	N/A	Option B: Steep-sloped (≥2:12): CZ 9: NR	Mandatory: N/A Prescriptive: Yes
Roofing: Thermal Emittance	Steep-sloped (≥2:12), CRRC-rated Thermal Emittance = 0.75	N/A	Option B: Steep-sloped (≥2:12): CZ 9: NR	Mandatory: N/A Prescriptive: Yes

Wall Insulation

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Demising walls at exterior closets	R-21 wood frame, 5/8” gypsum board: U-factor=0.065	Wood frame demising walls: U-factor ≤ 0.099	Wood frame demising walls: U-factor ≤ 0.099	Mandatory: Yes Prescriptive: Yes
Opaque exterior doors (< 25% glass)	Fire rated dwelling unit entry doors with U-factor = 0.20	N/A	All CZ: Dwelling unit entry doors: U-factor ≤ 0.20	Mandatory: N/A Prescriptive: Yes

Floor Insulation

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Floors over exterior closets	R-19 wood framed demising floors	U-factor ≤ 0.037 or insulation R-value ≥ R-19 in wood framing	U-factor ≤ 0.037 or insulation R-value ≥ R-19 in wood framing	Mandatory: Yes Prescriptive: Yes
Verifications	HERS QII Enclosure Air Leakage (tied to exhaust fan ventilation)	Mandatory Enclosure Air Leakage (tied to exhaust fan ventilation)	CZ 9: HERS QII required for multifamily buildings less than or equal to three habitable stories	Mandatory: Yes Prescriptive: Yes

Source: California Energy Commission

Note that the 2022 Energy Code has a new prescriptive calculation method for total allowed fenestration area. Instead of requiring either a percentage of the conditioned floor area or a percentage of the gross wall area, the 2022 Energy Code limits multifamily buildings to the smaller of 20 percent of the conditioned floor area and 40 percent of the gross exterior wall area. In this example, 20 percent of the conditioned floor area equals 1,443 ft^2 and 40 percent of the exterior wall area equals 1,959 ft^2, so the Prescriptive total fenestration area cannot be more than 1,443 ft^2. The proposed total fenestration area is only 700 ft^2, so it meets the Prescriptive requirement.

The building envelope meets all mandatory requirements and some prescriptive requirements except for the exterior wall insulation and the roof design in combination with the duct location.

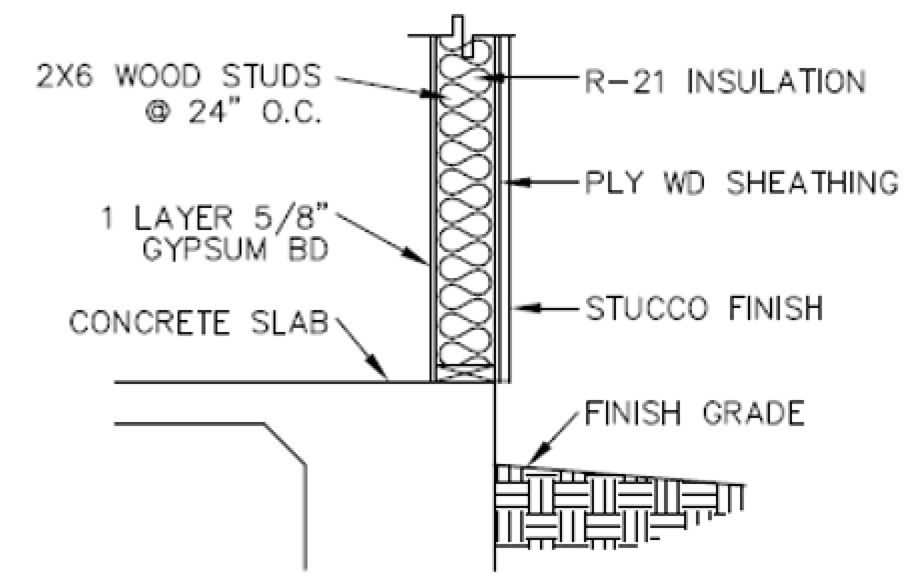
The exterior framed walls for this example building need a U-factor less than or equal to 0.051 to comply with the prescriptive approach, but the proposed design has framed wall U-factor equal to 0.065. Per Reference Appendices. Joint Appendix JA4 Table 4.3.1(a) one option for Prescriptive compliance would be to add R-4 continuous insulation to the planned wall assembly for a U-factor of 0.049.

The proposed design has ducts in a vented attic with R-30 ceiling insulation, but no roof insulation. Prescriptive Option B allows ducts in the attic, but that option also requires ceiling insulation, below-deck roof insulation, and an air space between the roofing material and the roof sheathing. Prescriptive Option C allows just ceiling insulation, but only if the ducts and the air handling units are all in conditioned space. The design team could make changes to the roof design or duct location to comply prescriptively, but they may not want to.

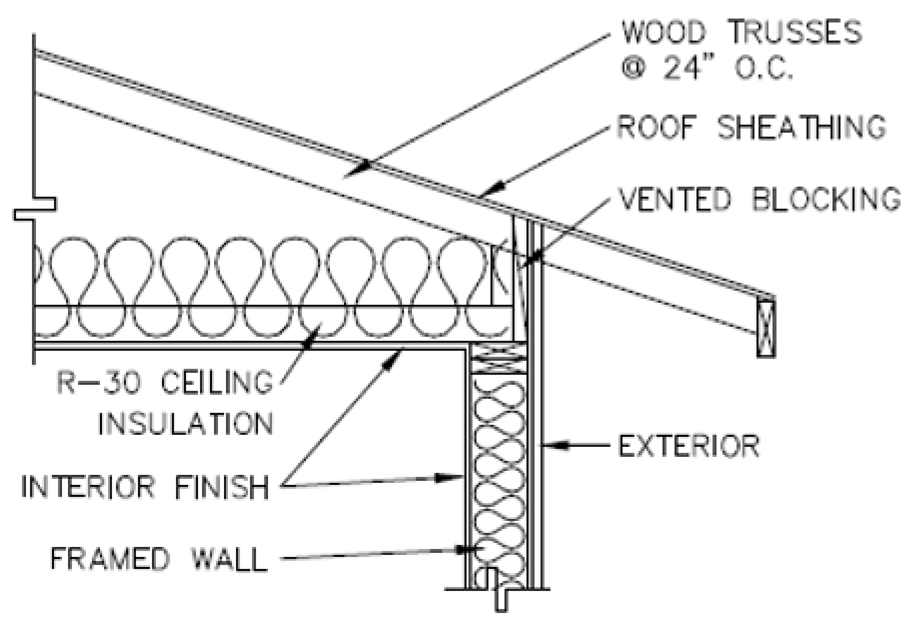
If the design team chooses to keep the original wall insulation and proposed roof construction combined with duct location, then the project will need to show compliance using the Performance Approach.

Figure 13: R-21 Framed Wall and R-30 Attic Roof Details

1 Hour Fire-Rated R-21 Wood Framed Wall



R-30 Vented Attic Roof with Wood Framed Raised Heel Truss



11.3.7.2 Mid-Rise Multifamily Case Study

The Mid-Rise Multifamily Case Study covers a new five-story multifamily building in Sacramento, California (Climate Zone (CZ) 12). This is a sample project created for training purposes, and it includes 112,044 square feet (ft²) of conditioned floor area with 88 dwelling units, shared residential corridors, laundry rooms, fitness center and lounge, plus ground floor retail. The case study tables in this chapter compare the proposed building envelope features to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Figure 14: Mid-Rise Multifamily: North and West View

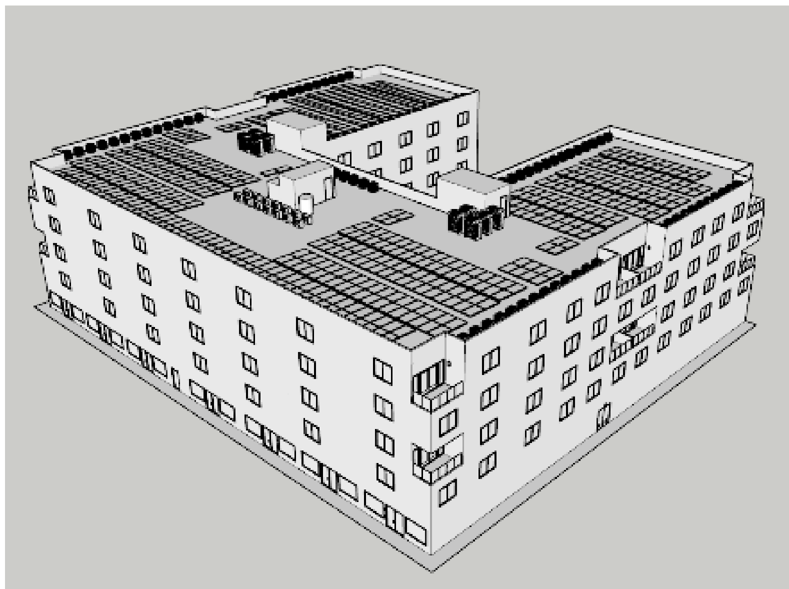


Figure 15: Mid-Rise Multifamily: South and East View

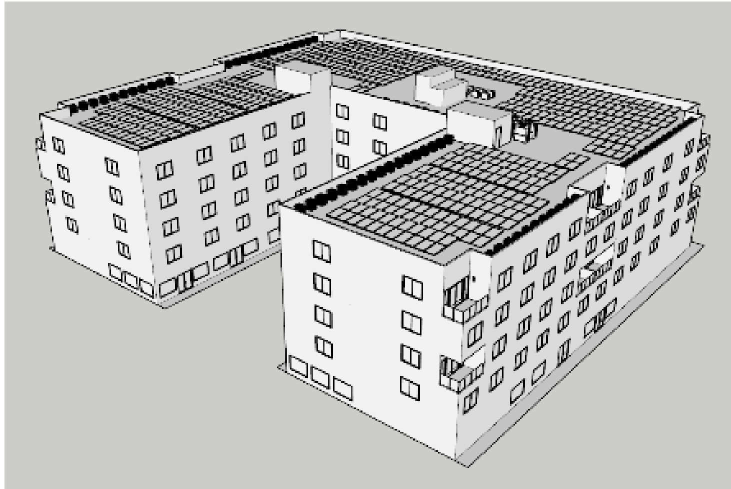


Table 11-17: Mid-Rise Multifamily Case Study Compared to Mandatory and Prescriptive Envelope Requirements (Climate Zone 12)

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Mid-Rise Multifamily Building	New five-story mid-rise multifamily building, 88 dwelling units, multifamily common use areas, ground floor retail, Sacramento, CA	Sections 100.0(f), 110.6, 110.7, 110.8, 120.7, 160.1	Section 100.0(f), Section 170.2(a), Table 170.2-A Section 140.3, Table 140.3-B New mixed occupancy multifamily plus nonresidential building ≥ four stories, Climate Zone (CZ) 12	Case study Mandatory and Prescriptive compliance rated for each feature below as "Yes" (complies), "No" (does not comply) or "N/A" (not applicable). If "No", see compliance options provided.
Conditioned Floor Area (CFA)	Dwelling Units: 78,384 ft²	78,384 ft²		
	Common Use Multifamily: 17,487 ft²	17,487 ft²		
	Nonresidential: 16,173 ft²	16,173 ft²		
	Total: 112,044 ft²	112,044 ft²		

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Total Percent Multifamily in Mixed Occupancy Building	(78,384 + 17,487)/ 112,044 = 85.6%	Mandatory features required for each occupancy type	Because multifamily is ≥ 80% of total CFA, the whole building envelope has the option of complying with multifamily Prescriptive, or could comply by separate occupancies	

Total Conditioned Floor Area and Fenestration

Source: California Energy Commission

Figure 16: Section 100.0(f) Exception 1 for Mixed Occupancy

Mixed Occupancy. When a building is designed and constructed for more than one type of occupancy (residential and nonresidential), the space for each occupancy shall meet the provisions of Part 6 applicable to that occupancy.

EXCEPTION 1 to Section 100.0(f): If one occupancy constitutes at least 80 percent of the conditioned floor area of the building, the entire building envelope, HVAC, and water heating may be designed to comply with the provisions of Part 6 applicable to that occupancy, provided that the applicable lighting requirements in Sections 140.6 through 140.8, 150.0(k), or 160.5 and 170.2(e) are met for each occupancy and space, and mandatory measures in Sections 110.0 through 130.5, 150.0, and 160.0 through 160.9 are met for each occupancy and space.

Table 11-18: Fenestration Case Studies Types and Locations

1st Floor: Mixed Occupancy: Retail (Nonresidential) and Multifamily Common Use

Storefront Fixed, Swinging Doors: NFRC-Rated dual pane low-e glass, thermal break metal frame

2nd-5th Floors: Multifamily Dwelling Units and Multifamily Common Use

Horizontal Sliders, Sliding Glass Doors, Fixed Sidelites: Manufactured NFRC-rated, Architectural Window (AW) Performance Grade, dual pane, low-e glass, vinyl frame

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
U-factor: All NFRC-rated	1st: Storefront Fixed: U-factor = 0.32	Multifamily (MF): ≤ 0.58 Retail: N/A	CZ 12: MF: ≤ 0.41 CZ 12: Retail: ≤ 0.41	Mandatory: Yes Prescriptive: Yes
	1st: Storefront Glazed Doors: U-factor = 0.41	MF: ≤ 0.58 Retail: N/A	CZ 12: MF: ≤ 0.41 All CZ: Retail: ≤ 0.45	Mandatory: Yes Prescriptive: Yes
	2nd-5th: AW Sliders: U-factor = 0.29	MF: ≤ 0.58	CZ 12: MF: ≤ 0.40	Mandatory: Yes Prescriptive: Yes

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
	3rd, 5th: AW Fixed: U-factor = 0.26	MF: ≤ 0.58	CZ 12: MF: ≤ 0.40	Mandatory: Yes Prescriptive: Yes
	3rd, 5th: AW Glazed Doors: U-factor = 0.29	MF: ≤ 0.58	CZ 12: MF: ≤ 0.40	Mandatory: Yes Prescriptive: Yes
RSHGC: All NFRC-rated	Storefront Fixed: RSHGC = 0.22	N/A	CZ 12: MF: ≤ 0.26 CZ 12: Retail: ≤ 0.26	Mandatory: N/A Prescriptive: Yes
	Storefront Glazed Doors: RSHGC = 0.19	N/A	CZ 12: MF: ≤ 0.26 CZ 12: Retail: ≤ 0.23	Mandatory: N/A Prescriptive: Yes
	AW Sliders: RSHGC = 0.22	N/A	CZ 12: MF: ≤ 0.24	Mandatory: N/A Prescriptive: Yes
	AW Fixed: RSHGC = 0.22	N/A	CZ 12: MF: ≤ 0.24	Mandatory: N/A Prescriptive: Yes
	AW Glazed Doors: RSHGC =0.22	N/A	CZ 12: MF: ≤ 0.24	Mandatory: N/A Prescriptive: Yes
Visible Transmittance (VT)	Storefront Fixed: VT = 0.47	N/A	All CZ: MF: ≥ 0.46 All CZ: Retail: ≥ 0.46	Mandatory: N/A Prescriptive: Yes
	Storefront Glazed Doors: VT = 0.41	N/A	All CZ: MF: ≥ 0.46 All CZ: Retail: ≥ 0.17	Prescriptive: MF: No, Retail: Yes Compliance Options: 1. Change to VT ≥ 0.46 2. Performance Approach
	AW Sliders: VT = 0.52	N/A	All CZ: MF: ≥ 0.37	Mandatory: N/A Prescriptive: Yes
	AW Fixed: VT = 0.53	N/A	All CZ: MF: ≥ 0.37	Mandatory: N/A Prescriptive: Yes
	AW Glazed Doors: VT = 0.52	N/A	All CZ: MF: ≥ 0.37	Mandatory: N/A Prescriptive: Yes

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Multifamily: Total Fenestration Area, Window Wall Ratio (WWR), Window Floor Ratio (WFR)	Total Fenestration: 6,802 ft² Walls: 36,030 ft² CFA: 95,871 ft² WWR: 6,802 / 36,030 = 18.9% WFR: 6,802 / 95,871 = 7.1%	N/A	*The smaller of* 40% WWR: 14,412 ft² and 20% WFR: 19,174 ft² Total Fenestration ≤ 14,412 ft²	Mandatory: N/A Prescriptive: Yes
Retail: Total Fenestration Area, WWR	Total Fen.: 1,442 ft² Walls: 6,702 ft² WWR: 21.5%	N/A	≤ 40% WWR: Total Fenestration ≤ 2,681 ft²	Mandatory: N/A Prescriptive: Yes

Source: California Energy Commission

Table 11-19: Roof, Wall, and Floor, plus Verifications Case Studies

Roof and Ceiling: Insulation, Radiant Barrier and Roofing

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
5th Floor: Rafter Roof 2nd and 4th Floor: Deck Roofs (same insulation and framing)	Roof Insulation: 2x12 wood framing 24" o.c., R-30 cavity insulation: U-factor = 0.033 Radiant Barrier: No	Wood framed non-attic roofs require an area-weighted U-factor ≤ 0.075	Option D: For CZ 12, wood framed non-attic roofs require an area-weighted U-factor ≤ 0.028 Radiant Barrier: NR	Mandatory: Yes Prescriptive: No Compliance Options: 1. Change to R-38 cavity insulation in 2x12 wood framing 24" o.c. for a U-factor = 0.028 2. Performance Approach
Roofing: Aged Solar Reflectance	Low-sloped (<2:12), No cool roof	N/A	Option D: Low-sloped (<2:12): CZ 12: NR	Mandatory: N/A Prescriptive: Yes
Roofing: Thermal Emittance	Low-sloped (<2:12), No cool roof	N/A	Option D: Low-sloped (<2:12): CZ 12: NR	Mandatory: N/A Prescriptive: Yes

Wall Insulation (Note: Mandatory maximum U-factors must be met for Performance compliance options.)

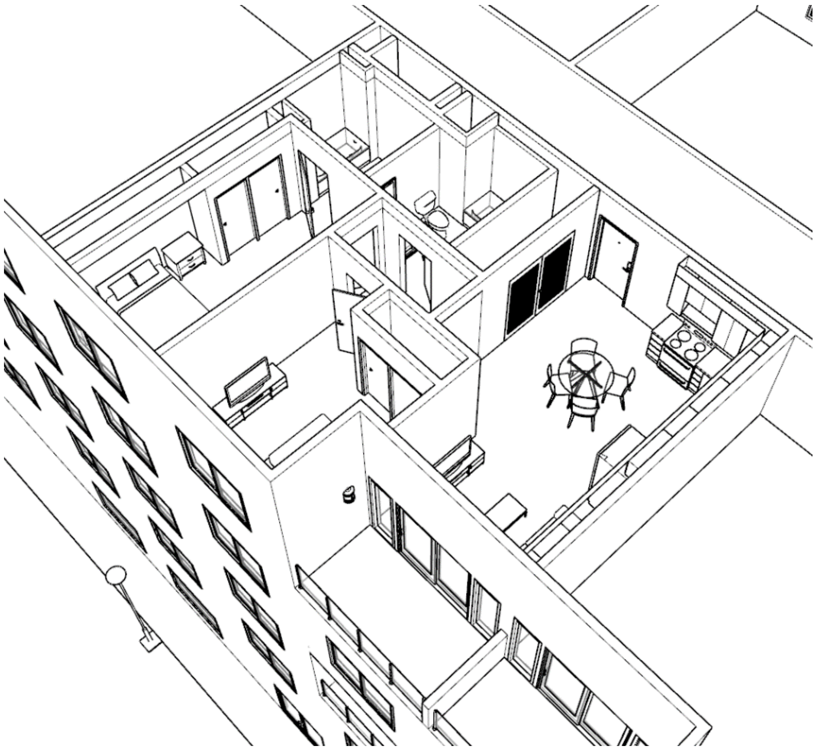
	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
1st Floor West elevation and 1st-	8" solid concrete	MF and Retail:	CZ12: MF and Retail:	Mandatory: No

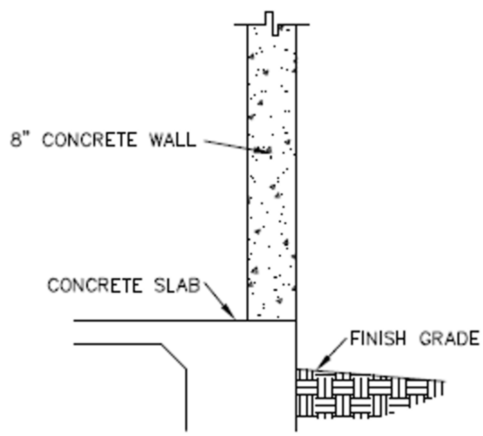
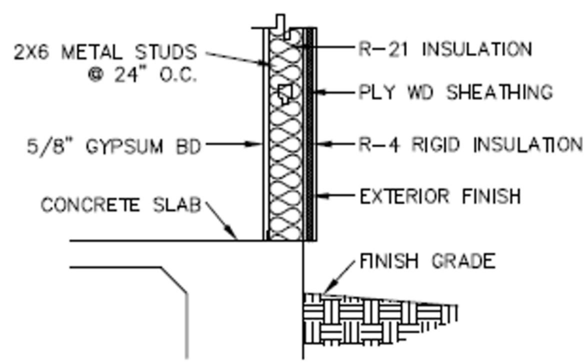
	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
5th Floor stairwells: 8" concrete	U-factor = 0.740	Heavy mass wall U-factor ≤ 0.690	Heavy mass wall U-factor ≤ 0.253	Prescriptive: No Compliance Options: 1. Add R-3 continuous insulation to walls for U-factor = 0.230 2. Performance Approach
1st Floor: All others: ≤ 1 hr. fire-rated metal frame	6" metal frame 24" o.c., R-21 cavity insulation, R-4 continuous insulation, 5/8" gypsum board: U-factor = 0.098	MF and Retail: Metal framed walls: U-factor ≤ 0.151	MF: All CZ: Framed wall ≤1 hr. fire rated: U-factor ≤ 0.051 Retail: CZ12: Metal framed U-factor ≤ 0.055	Mandatory: Yes Prescriptive: No Compliance Options: 1. Change to R-14 continuous insulation for U-factor ≤ 0.049 2. Performance Approach
2nd-5th Floors: > 1 hr. fire-rated wood framed walls	2x6 wood frame 24" o.c., R-21 cavity insulation, R-4 continuous, (2) 5/8" gypsum board: U-factor = 0.049	Nominal 2x6 wood framed walls: U-factor ≤ 0.071	CZ12: Framed wall >1 hr. fire rated: U-factor ≤ 0.051	Mandatory: Yes Prescriptive: Yes

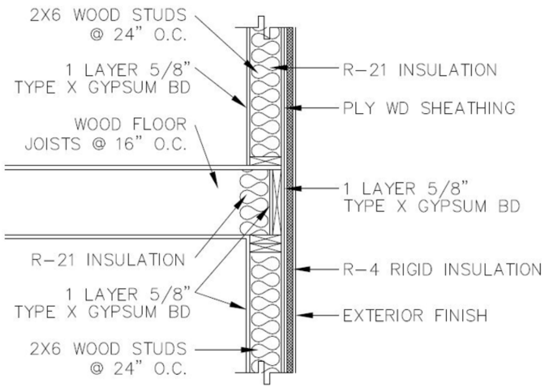
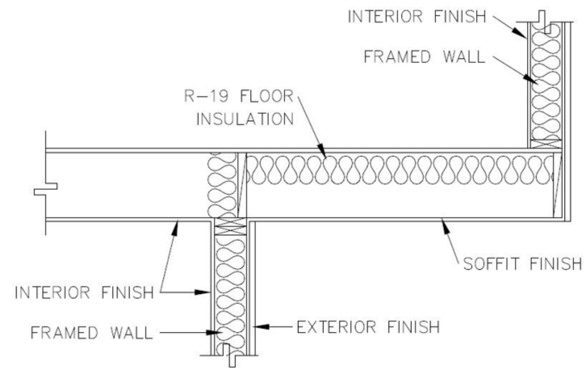
Floor Insulation

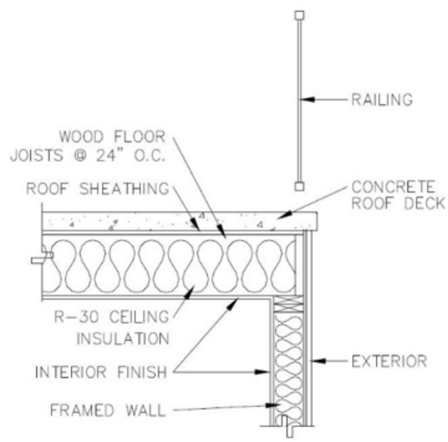
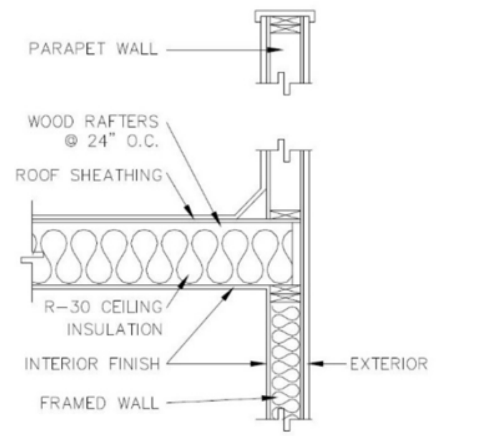
	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Slab on grade	Uninsulated	NR	NR	Mandatory: Yes Prescriptive: Yes
Raised Floor over inset balcony on floor below	R-19 wood framed floors	U-factor ≤ 0.037 or insulation R-value ≥ R-19 in wood framing	U-factor ≤ 0.037 or insulation R-value ≥ R-19 in wood framing	Mandatory: Yes Prescriptive: Yes
Verifications	None	N/A	N/A	Mandatory: N/A Prescriptive: N/A

Figure 17: Mid-Rise Multifamily: 5th Floor, 2-Bedroom Apartment, Plan View with North and East Elevations



8" Concrete Wall	1st Floor: Metal Framed Wall
	

2nd – 5th Floors: R-21+R-4 Wood Framed Wall	R-19 Wood Framed Raised Floor over Balconies
	

2nd and 4th: R-30 Wood Framed Deck Roof	5th Floor: R-30 Wood Framed Rafter Roof
	

This case study is a mixed occupancy building with 85.6 percent multifamily dwelling units and common use areas and 14.4 percent nonresidential retail spaces. According to Energy Code Section 100.0(f) Exception 1, if one occupancy in a mixed use building is at least 80 percent of total conditioned floor area, the whole building has the option of complying with the Prescriptive requirements of the dominant occupancy. Note that each separate occupancy type still has to comply with its own lighting requirements and mandatory requirements.

For this case study, the whole building envelope could either meet multifamily prescriptive requirements, or the nonresidential and multifamily areas could comply separately. Based on the results shown in the comparison table, it probably makes sense to show compliance separately for the retail and multifamily areas in this case study. All of the case study envelope features at least meet Mandatory U-value requirements, except for the uninsulated concrete walls on the west side of the first floor and at the stairwells.

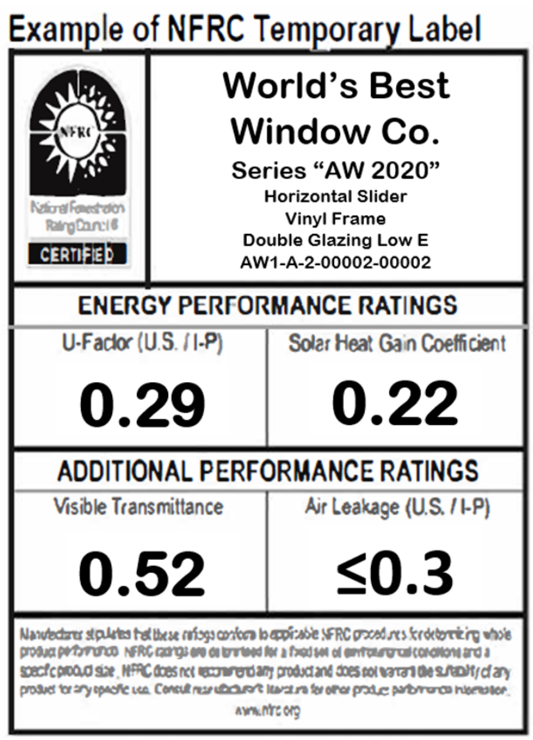
There is no alternative to meeting Mandatory requirements, even for performance method compliance. Those concrete walls will have to have a maximum U-factor of

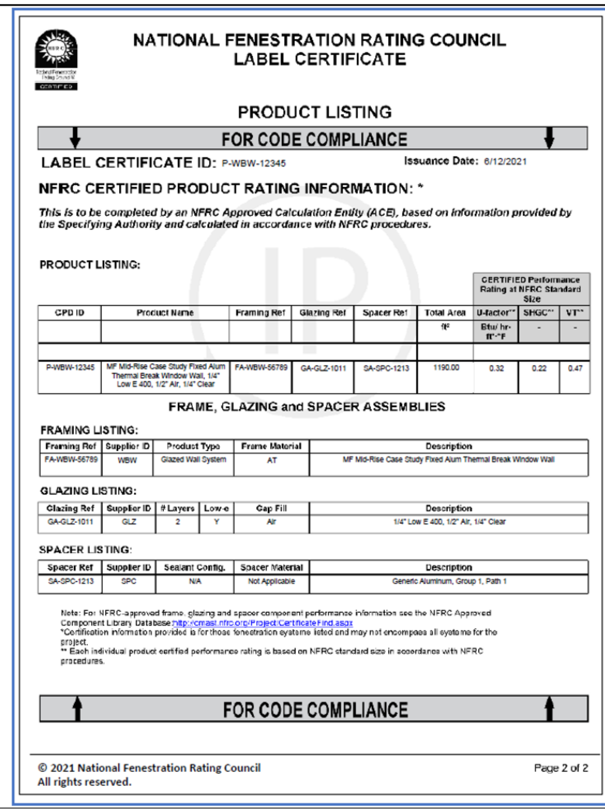
0.690 instead of the proposed U-factor of 0.740 for the project overall to comply at all.

The table also shows several design features that meet mandatory requirements, but do not comply prescriptively. If even one measure misses the prescriptive requirements, the overall project fails prescriptive compliance. In that situation, the project owners and design team would need to make changes to the design to show prescriptive compliance or else work with an energy analyst to evaluate the building using the performance approach to find trade-offs between different building features. Note that the Performance Approach usually works best when modeling the building envelope together with other building components such as the mechanical and water heating systems, since that may allow more opportunities for trade-offs.

Figure 18: NFRC Label (Units) AW Rating & NFRC certificate (Storefront)

NFRC Label Dwelling Units: AW Rating	NFRC Certificate: Storefront





NATIONAL FENESTRATION RATING COUNCIL
LABEL CERTIFICATE

PRODUCT LISTING

FOR CODE COMPLIANCE

LABEL CERTIFICATE ID: P-WBW-12345 Issuance Date: 6/12/2021

NFRC CERTIFIED PRODUCT RATING INFORMATION: *

This is to be completed by an NFRC Approved Calculation Entity (ACE), based on information provided by the Specifying Authority and calculated in accordance with NFRC procedures.

PRODUCT LISTING:

CPD ID	Product Name	Framing Ref	Glazing Ref	Spacer Ref	Total Area	CERTIFIED Performance Rating at NFRC Standard Size U-factor**	SHGC**	VT**
					ft²	Btu/ hr-ft²-°F	-	-
P-WBW-12345	MF Mid-Rise Case Study Fixed Alum Thermal Break Window Wall, 1/4" Low E 400, 1/2" Air, 1/4" Clear	FA-WBW-56789	GA-GLZ-1011	SA-SPC-1213	1190.00	0.32	0.22	0.47

FRAME, GLAZING and SPACER ASSEMBLIES

FRAMING LISTING:

Framing Ref	Supplier ID	Product Type	Frame Material	Description
FA-WBW-56789	WBW	Glazed Wall System	AT	MF Mid-Rise Case Study Fixed Alum Thermal Break Window Wall

GLAZING LISTING:

Glazing Ref	Supplier ID	# Layers	Low-e	Gap Fill	Description
GA-GLZ-1011	GLZ	2	Y	Air	1/4" Low E 400, 1/2" Air, 1/4" Clear

SPACER LISTING:

Spacer Ref	Supplier ID	Sealant Config.	Spacer Material	Description
SA-SPC-1213	SPC	N/A	Not Applicable	Generic Aluminum, Group 1, Path 1

Note: For NFRC-approved frame, glazing and spacer component performance information see the NFRC Approved Component Library Database http://cmast.nfrc.org/ProjectCertificateFind.aspx
*Certification information provided is for those fenestration systems listed and may not encompass all systems for the project.
** Each individual product certified performance rating is based on NFRC standard size in accordance with NFRC procedures.

FOR CODE COMPLIANCE

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Source: California Statewide CASE team

Figure 19: 1st : 8" Concrete Wall (2022 Ref. App. Fig. 4.3.6)

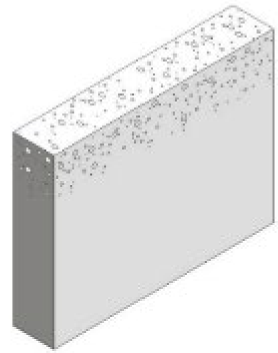


Figure 20: Metal Framed Wall

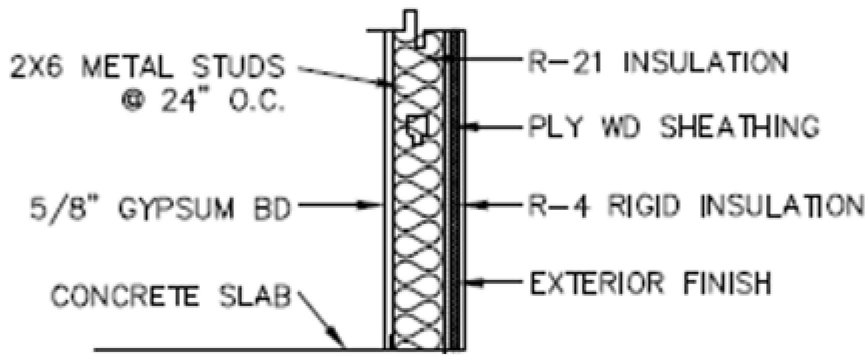


Figure 21: 1 Hour Fire-Rated R-21 Wood Framed Wall

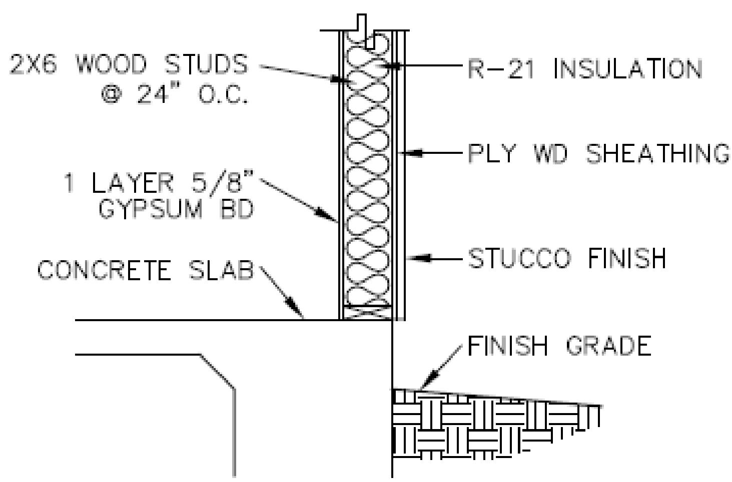


Figure 22: 5th: Wood Frame Rafter Roof (2022 Ref. App. Fig. 4.2.2)

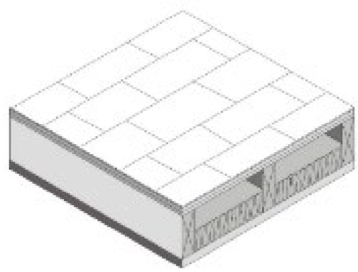


Figure 23: 2nd and 4th: Deck Roofs (2022 Ref. App. Fig. 4.2.2)

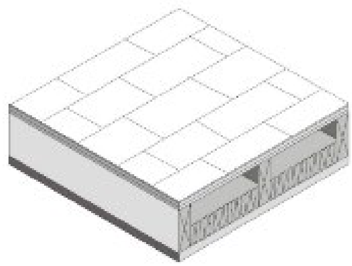
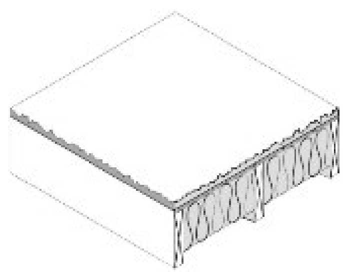


Figure 24: 4th: Raised Floor (2022 Ref. App. Fig. 4.4.2)



On a different note, this case study highlights that there are separate Prescriptive multifamily fenestration U-factor, RSHGC and visible transmittance (VT) requirements for products certified to meet the North American Fenestration Standard/Specification (NAFS) for an Architectural Windows (AW). AW performance grade windows are designed to withstand high wind loads or other physical loads, and for this study the design team determined that they were needed for all of the dwelling units to address a very windy site location. AW performance grade fenestration is generally seen in high-rise and mid-rise buildings. U-factor, RSHGC and VT values for AW performance grade fenestration still need to be determined through NFRC rating or other methods defined in Energy Code Section 110.6.

11.4 Building Indoor Air Quality and Ventilation Requirements

This section addresses the requirements for indoor air quality (IAQ) and ventilation in multifamily buildings and is organized as shown in Table 11-20. Sections 11.4.1 through 11.4.5 discuss IAQ and ventilation requirements for dwelling units, and Section 11.4.6 discusses ventilation requirements for common use areas, including corridors, community rooms, common laundry rooms, exercise facilities, and other areas outside of dwelling units.

Table 11-20: Overview of Indoor Air Quality and Ventilation Requirements in the Energy Code and Compliance Manual Organization

Ventilation System Application	Mandatory Requirements	Prescriptive Requirements	Performance Approach Requirements	Manual Section
Ventilation System Serving Individual Dwelling Units	§160.2	§170.2(c)3,3Biii,3Biv,4A	§170.1	11.4.2
Central Ventilation Systems Serving Dwelling Units	§160.2	N/A	N/A	11.4.3
Air Moving Equipment	§160.2(b)2	N/A	N/A	11.4.4
Dwelling Unit Additions and Alterations	N/A	§180.1(a)2 §180.2(b)5	§180.1(b)5	11.4.6
Common Use Area Ventilation Requirements	§160.2(c) §160.2(d) §160.3(d)1	§170.2(c)4	§170.1	4.3
Other Requirements	§160.2(b)2	N/A	N/A	11.4.5

Source: California Energy Commission

Heating and cooling requirements for multifamily dwelling units are provided in Section 11.5.

11.4.1 What's New for the 2022 Energy Code

The following is an overview of the new multifamily IAQ and ventilation requirements for the *2022 Building Energy Efficiency Standards* (Energy Code).

11.4.1.1 Mandatory Features and Devices

For dwelling units:

- Unitary energy recovery ventilators (ERVs) and heat recovery ventilators (HRVs) (one unit serving each dwelling unit) are required to meet a maximum fan efficacy of 1.0 W/CFM.
- If a vented range hood is used for the exhaust system in the dwelling unit kitchen, the range hood must either meet a minimum capture efficiency or airflow dependent on the range fuel and the floor area of the dwelling unit to ensure adequate removal of cooking-related pollution.
- Central ventilation duct systems that provide continuous ventilation airflow or serve as part of dwelling units' balanced ventilation must be sealed to ensure leakage does not exceed:
  - 10% of the central (e.g., rooftop) fan airflow rate at 50 Pa (0.2 inches w.c.) for central ventilation duct serving more than six dwelling units
  - 6% of the central fan airflow rate at 25 Pa (0.1 inches w.c.) for central ventilation duct serving six or fewer dwelling units
- Updated ventilation requirements based on applicable sections of 2019 ASHRAE 62.2 and added clarification language.
- Filter racks or grilles must use a gasket or sealing to prevent air from bypassing the filter.

For common use areas:

- Common use areas are required to have occupant sensing ventilation controls if the space conditioning zones are permitted to have ventilation air reduced to zero or if occupant sensors are used to comply with lighting requirements. Occupant sensor ventilation control devices must comply with §160.2(c)E.
- Filter racks or grilles must use a gasket or sealing to prevent air from bypassing the filter.

11.4.1.2 Prescriptive Requirements

For dwelling units:

- In Climate Zones 4-10, if the ventilation system is a balanced system without heat or energy recovery, the fan efficacy must be 0.4 W/CFM or less.
- In Climate Zones 1-2 and 11-16, for projects following the balanced ventilation path, the prescriptive approach requires an ERV or HRV.
  - Unitary ERV or HRV equipment (one unit serving each dwelling unit) must be field verified to have a sensible heat recovery efficiency of at least 67% and fan efficacy less than or equal to 0.6 W/CFM.

- Central ERV or HRV equipment (one unit serving multiple dwelling units) must be field verified to have a minimum sensible heat recover effectiveness of 67%, have minimum fan efficacy as required in §170.2(c)4a, and include a bypass or free cooling function whereby the intake air bypasses the heat exchanger during favorable outdoor air temperatures.

For common use areas:

- Common use areas using a dedicated outdoor air system (DOAS) to condition, temper, or filter 100% outdoor air separate from local or central space-conditioning systems serving the same space must meet new criteria specified in §170.2(c)4N. This includes requirements for heat recovery, an energy recovery bypass or control to directly economize with ventilation air, modulating fan speed control capabilities, fan efficacy requirements, and (for airflows > 1,000 cfm) demand control ventilation requirements.
- Common use area fan systems that operate to criteria shown in Table 170.2-I or Table 170.2-J need to include an exhaust air heat recovery system that meet the requirements in §170.2(c)4O

11.4.1.3 Additions and Alterations

New to the Energy Code, there are explicit triggers for whole-dwelling unit mechanical ventilation system alterations including ventilation fans, air filters, and local mechanical exhaust systems.

There are no new requirements common use areas for additions or alterations. Additions to the common use area should follow the nonresidential building requirements. Any newly installed space conditioning system must meet the ventilation requirements in §120.1 (Requirements for Ventilation and Indoor Air Quality) for both the prescriptive and performance approaches.

11.4.2 Dwelling Unit IAQ and Mechanical Ventilation

As multifamily buildings have been tightened to improve energy performance, the dilution of indoor air through natural ventilation has been significantly reduced. As a result, the importance of controlling indoor pollutants generated by kitchen ranges during food preparation and (where applicable) from gas stoves. Cleaning products, furniture, dry cleaning, personal care products, and other sources may have increased. Without local exhaust to remove pollutants from areas such as kitchens and bathrooms, and dwelling unit ventilation to dilute pollutants throughout the dwelling unit, IAQ will be poor. This can negatively impact occupant health and (due to high relative humidity) the integrity of the building.

This section covers typical design solutions, energy consumption issues, and other requirements specified by ASHRAE Standard 62.2 as amended in the Energy Code.

11.4.2.1 Dwelling Unit Mandatory Requirements

§160.2

A. Overview of Requirements

Multifamily dwelling units must meet the requirements of ASHRAE Standard 62.2-2019 including Addenda v and d subject to the amendments specified in §160.2(b)2A. A copy of this version of ASHRAE Standard 62.2 may be obtained at the following link: www.techstreet.com/ashrae/standards/ashrae-62-2-2019?product_id=2087691

As part of mandatory requirements, all dwelling units must have mechanical ventilation, Minimum Efficiency Reporting Value (MERV) 13 air filtration on space conditioning systems, and ventilation systems that provide outside air to the occupiable space of a dwelling. Opening and closing windows and continuous operation of central fan-integrated ventilation systems are not allowable options for meeting dwelling unit ventilation requirements. The requirements of ASHRAE Standard 62.2 focus on providing continuous whole-dwelling unit mechanical ventilation, as well as local exhaust ventilation at known sources of pollutants or moisture, such as kitchen, bathroom, and laundry. The key mandatory requirements for mechanical ventilation for most newly constructed multifamily buildings are:

- A whole-dwelling unit mechanical ventilation system must be provided. Typical solutions are described in Section 11.4.2.10 Dwelling Unit Ventilation Strategies section below. The airflow rate provided by the system mustmust be confirmed through field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Residential Appendix RA3.7.
- Dwelling units must either use balanced ventilation or meet a compartmentalization (dwelling unit air sealing) requirement.
- Kitchens and bathrooms must have local exhaust systems vented to the outdoors.
- Clothes dryer exhaust must be vented to the outdoors.

The following additional IAQ design mandatory requirements apply:

- Ventilation air mustmust come from outdoors and must not be transferred from adjacent conditioned spaces, garages, or unconditioned spaces.
- Combustion appliances must be properly vented, and exhaust systems must be designed to prevent back drafting.
- Walls and openings between the dwelling unit and adjacent spaces, such as adjacent units, a common corridor, trash chute, parking garage, or other spaces must be sealed or gasketed.
- Mechanical systems, including ventilation systems, that supply air to habitable spaces mustmust be designed to filter recirculated air and outdoor air through a MERV 13 filter or better and mustmust be designed to accommodate the rated pressure drop of the system air filter at the designed airflow rate.
- Dedicated outdoor air inlets that are part of the ventilation system design mustmust be located away from known sources of outdoor contaminants.

- A carbon monoxide alarm mustmust be installed in each dwelling unit in accordance with NFPA Standard 720.
- Air-moving equipment used to meet the whole-dwelling unit ventilation requirement and the local exhaust requirement, including kitchen local mechanical exhaust, mustmust be rated by HVI or AHAM, which provides ratings for kitchen local mechanical exhaust, for airflow and sound:
    - Whole-dwelling unit ventilation and continuously operating local exhaust fans must be rated at a maximum of 1.0 sone (measurement of sound).
    - Demand-controlled local exhaust fans must be rated at a maximum of 3.0 sone.
    - Kitchen exhaust fans must be rated at a maximum of 3.0 sone at one or more airflow settings greater than or equal to 100 CFM. (As described in Section 11.4.2 0, the Standard requires kitchen range hoods to have a higher airflow than 100 CFM, but the range hoods must be tested for sound at a minimum of 100 CFM.)
    - Remotely located air-moving equipment (mounted outside habitable space, bathrooms, toilets, and hallways) is exempt from the sound requirements provided there is at least 4 ft. of ductwork between the fan and the interior grille. Kitchen range hoods are also exempt from the sound requirements provided they have a minimum airflow setting exceeding 400 cfm.
- For central ventilation systems serving multiple dwelling units, ducts must be sealed, balanced, and (for some systems) tested for leakage.

11.4.2.2 Summary of Field Verification and Testing Requirements by a HERS Rater or ATT

Compliance with the Standard requirements must be verified by the enforcement agency, except for the following requirements. Table 11-1 shows the ventilation and IAQ HERS Verifications that must be conducted by either a HERS Rater or ATT, where "stories" refers to habitable stories. As shown, the Energy Code generally requires that some HERS raters verify some features and that ATTs verify others. NA1.9 allows ATTs to serve as HERS raters in multifamily buildings with four or more stories. The builder is free to choose either a HERS Rater or ATT to perform the eligible HERS verifications, but that choice must be approved by the enforcement agency (NA1.9.1).

Table 11-21: Ventilation and IAQ Field Verification and Testing Requirements by a HERS Rater or ATT

Feature	Verification Requirement	Authorized for verification: HERS Rater and/or ATT
Dwelling unit air leakage (compartmentalization)	Conduct air leakage test, also known as an individual dwelling unit blower door test, for a sample of dwelling units	HERS Rater
ERV/HRV	Verify ERV/HRV HVI-listing and compliance based on nominal airflow	HERS Rater
ERV/HRV	Verify nominal sensible recovery efficiency, and fan efficacy / fan power allowance	HERS Rater for three stories or lower, ATT for four stories or higher
ERV/HRV	Conduct functional bypass testing for central ERV/HRV (per NA 7.18.4)	ATT, for buildings four stories or higher (no equivalent requirement for buildings three stories or lower)
Kitchen exhaust	Verify using listings in HVI or AHAM-directories for compliance based on nominal airflow or capture efficiency, and sound	HERS Rater
Central ventilation duct sealing	Conduct a leakage test measurement (NA 7.18.3)	ATT, for buildings four stories or higher (no equivalent requirement for buildings three stories or lower)

Source: California Energy Commission

For HERS verification requirements, HERS raters must follow procedures in Residential Appendix RA3.7 and ATTs must follow procedures in Nonresidential Appendix NA2.1. Section 11.4.8 provides more detail on compliance and enforcement.

11.4.2.3 Differences between Energy Code and ASHRAE Standard 62.2

The Energy Code mandatory requirements include the adopted 2019 ASHRAE Standard 62.2 with amendments. The key differences in the Energy Code compared to the 2019 ASHRAE Standard 62.2 include the following:

- While ASHRAE Standard 62.2 requires compartmentalization but does not require balanced ventilation, the Energy Code provide two options for compliance with dwelling unit ventilation: 1) installation of a balanced ventilation system or 2) installation of an exhaust or supply-only system accompanied by compartmentalization: sealing to a leakage rate of not more than 0.3 CFM50 per square feet of dwelling unit enclosure surface area.

- The Energy Code require MERV 13 filtration for all recirculated air and outdoor air, including outdoor air provided by supply air ventilation systems or the supply side of balanced ventilation systems, while ASHRAE Standard 62.2 requires MERV 6 filtration for HVAC systems with at least 10 ft. of ductwork. The additional filtration requirements in the Energy Code are important for reducing particulate matter which can pose a health to residents.
- Both standards require kitchen exhaust systems vented to the outdoors and allow three systems for kitchen exhaust systems in multifamily dwelling units: 1) demand-controlled range hood, 2) downdraft exhaust or 3) continuous kitchen exhaust for enclosed kitchens only.
  - For demand-controlled range hoods, the Energy Code require that they either meet a minimum airflow or capture efficiency that depends on the type and dwelling unit floor area as shown in Table 11-22. There are no capture efficiency requirements in ASHRAE Standard 62.2. Additionally, the required minimum hood airflows are higher in the Energy Code, as shown in Table 11-22, than the requirement in ASHRAE Standard 62.2, which is 100 CFM for all demand-controlled range hoods.

Table 11-22: Minimum Capture Efficiency (CE) or Airflow (CFM) for Demand-Controlled Range Hoods

Dwelling unit floor area (sq. ft)	Hood over electric range	Hood over gas range
≤ 750	65% CE or 160 CFM	85% CE or 280 CFM
750 – 1,000	55% CE or 130 CFM	85% CE or 280 CFM
> 1,000 – 1,500	50% CE or 110 CFM	80% CE or 250 CFM
>1,500	50% CE or 110 CFM	70% CE or 180 CFM

Source: California Energy Commission

  - For downdraft and continuous kitchen exhaust requirements, the Energy Code and ASHRAE Standard 62.2 are the same.

The verification protocol for kitchen exhaust systems remains the same. Kitchen range hood fans are required to be verified by a HERS Rater. The verification protocol requires comparing the installed model to ratings in the Home Ventilating Institute (HVI) or Association of Home Appliance Manufacturers (AHAM) directory of certified ventilation products to confirm the installed range hood is rated to meet the required airflow in the Energy Code, as well as the sound requirements specified in ASHRAE Standard 62.2. See the section, ***Requirements for Kitchen Exhaust*** below for more detail. Kitchen range hood fans that exhaust more than 400 CFM at minimum speed are exempt from the sound requirement.

Limiting the sources of indoor pollutants is an important method for protecting IAQ. The United States Environmental Protection Agency (EPA) provides information and resources on improving IAQ. For more information, see the EPA's Indoor Air Quality webpage: /www.epa.gov/indoor-air-quality-iaq.

11.4.2.4 Dwelling Unit Ventilation Strategies

This section provides typical strategies for providing outdoor air for whole-dwelling unit ventilation. Local exhaust systems, which provide spot ventilation to remove polluted air from areas such as bathrooms and kitchen, are described in the section 11.4.2.1 0 Dwelling Unit Local Exhaust .

Multifamily projects can use either of the following strategies:

- Unitary ventilation system, in which each dwelling unit has its own ventilation system. These are often simpler designs and use packaged equipment, but present more systems to maintain, may require maintenance by the resident (or at least their cooperation to provide access), and can require more wall penetrations.
- Central ventilation systems, in which a centrally located (typically rooftop) fan and centralized ductwork serves multiple dwelling units. These can streamline maintenance and reduce exterior wall penetrations. For ERVs and HRVs, centralized equipment provides economies of scale for features such as bypass, which provides significant energy savings during the cooling season. However, centralized ventilation systems reduce the occupiable square footage in a building and can increase penetrations between units, which should be sealed for IAQ concerns.

There are generally three system types available for meeting the mandatory whole-dwelling unit ventilation requirements:

1. **Exhaust ventilation:** air is exhausted from the dwelling unit and replaced by infiltration—i.e., air entering the dwelling unit through cracks and leaks in the dwelling unit air barrier.
2. **Supply ventilation:** filtered outdoor air is supplied directly to the dwelling unit
3. **Balanced ventilation:** combination of exhaust and supply in which air is exhausted from a dwelling unit and outdoor air is supplied directly to the dwelling unit at the same rate (within 20%).

For the mandatory requirements of the Energy Code, §160.2(b)2Aivb requires the whole-dwelling unit ventilation system to either be a balanced system or a supply or exhaust system with compartmentalization testing. See section 11.4.2.10 for details on compartmentalization testing. Multifamily buildings must use one approach for compliance (either balanced ventilation, or supply or exhaust-only ventilation with compartmentalization throughout the entire building, per §160.2(b)2Aivb. Multifamily projects could implement both balanced ventilation and compartmentalization for best practice but are not required to do so.

Natural ventilation does not satisfy requirements for dwelling unit ventilation. All dwelling unit ventilation systems need to have a mechanical fan.

A. Exhaust-only

In an exhaust-only system, air is drawn from the dwelling unit and exhausted to the outdoors. Outdoor air enters the unit through infiltration. This infiltration air will include both outdoor air, as well as air from adjacent spaces in the building (e.g., corridor, adjacent units). While not prohibited, exhaust-only ventilation systems are not good practice in dwelling units that will have difficulty drawing adequate outside air due to limited exterior wall area.

Exhaust ventilation is typically provided using a continuously operating ceiling-mounted fan. Projects may use intermittent fans for meeting the dwelling unit ventilation rate, but these must be on a schedule to ensure that the minimum ventilation rate is met. Examples of intermittent ventilation systems can be found in ASHRAE 62.2 Section 4.5. Intermittent ventilation systems must be certified to the Energy Commission.

All fans must meet sound requirements: maximum of one sone for continuously operated and 3 sones for intermittent. Remotely located fans (fans mounted outside habitable spaces[2], bathrooms, toilets, and hallways) are exempt from the sound requirements if there is at least four feet of ductwork between the fan and the interior grille. For larger units, more than one fan may be needed to meet ventilation air requirements. The same fan can be used to meet dwelling unit and local (bathroom or laundry) exhaust ventilation requirements. Inline fans (fans mounted in line with ductwork) can be used to exhaust air from one or more bathrooms.

While not required, some multifamily units include passive air inlets, such as Z-ducts or trickle vents, to increase the rate of fresh air that enters the unit beyond natural infiltration. Since there is no filter in an exhaust-only dwelling unit ventilation system, MERV 13 filtration is not applicable to exhaust-only ventilation or air that enters via passive air inlets. However, MERV 13 filtration is still required in the dwelling unit for the separate space conditioning (heating or cooling) system, if it is a forced air system with ductwork exceeding 10 feet in length. Figure 11-26 provides an example of an exhaust-only ventilation strategy. While this example is shown for a garden style unit, the same approach could be used for a dwelling unit on a common corridor (in a building with a common entry).

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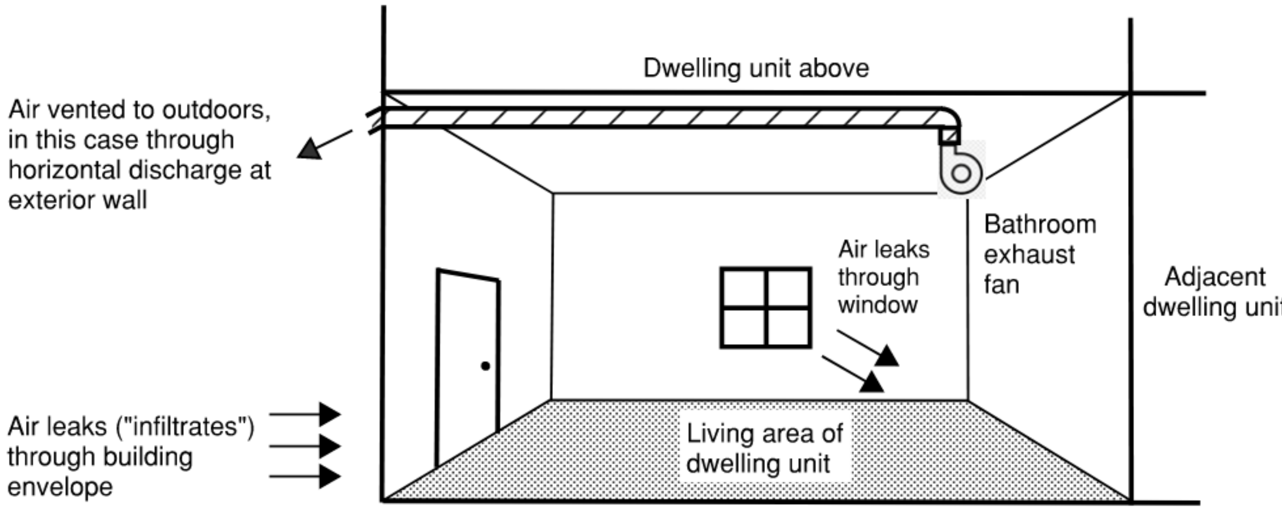
[2] Based on the definition in ASHRAE Standard 62.2, a habitable space is intended for continual human occupancy; and hallways, storage areas, closets, or utility rooms could be considered not habitable.

Figure 11-25: Exhaust Ventilation Example



Bathroom exhaust fans may serve a dual purpose to provide whole-dwelling unit ventilation operating at a low constant airflow rate and to provide local demand-controlled ventilation at a higher airflow rate, or boost, when needed. For these system types, the continuous whole-dwelling unit airflow operation must have an ON/OFF override, which may be located in the bathroom or in a remote accessible location. The boost function is controlled by a separate wall switch located in the bathroom or by a motion sensor or humidistat located in the bathroom.

A kitchen exhaust fan in an enclosed kitchen may also serve a dual purpose of whole-dwelling unit ventilation and kitchen ventilation if it meets both the minimum dwelling unit ventilation rate and the minimum requirement for kitchen exhaust (described in the Section Dwelling Unit Local Exhaust).

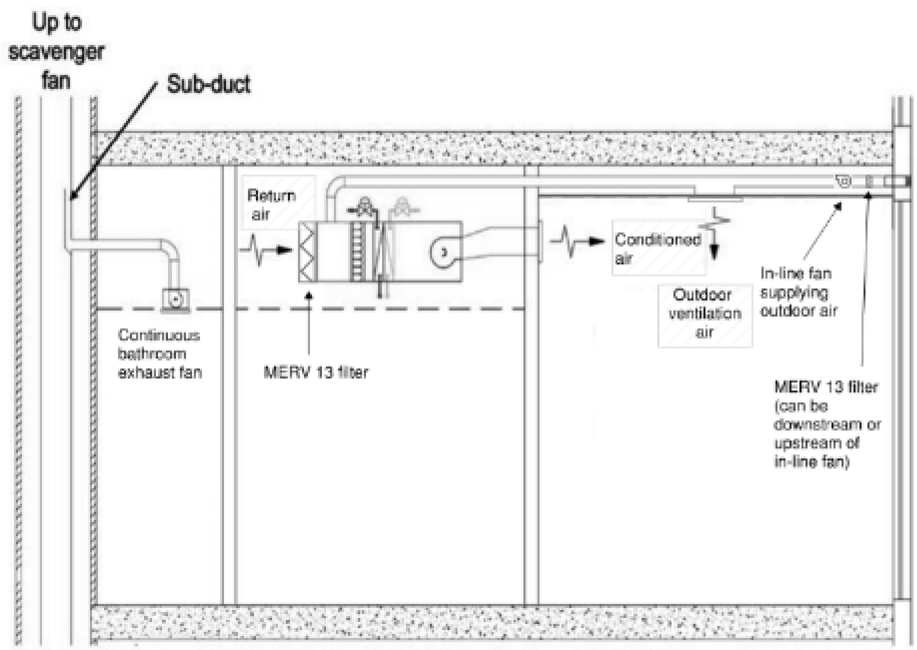
B. Supply Ventilation

Supply ventilation systems draw outdoor air into the unit using a dedicated supply fan. Indoor air escapes through leaks in the building envelope (exfiltration). Space conditioning system air handling units cannot be used to provide supply ventilation, unless they meet the Central Fan-Integrated Ventilation approach described in Section 11.4.2.10D.

Continuously operating ventilation fans must meet mandatory sound requirement of one sone or less. For larger dwelling units, more than one fan may be used. Remotely located fans (fans mounted outside habitable space, bathrooms, toilets, and hallways) are exempt from the sound requirements if there is at least four feet of ductwork between the fan and the interior grille.

§160.2(b)1 requires that outside air be filtered using MERV 13 (or greater) particle removal efficiency rated air filters. The filters must be accessible to facilitate replacement. Supply systems may locate the MERV 13 air filter either upstream or downstream of the fan as long as the incoming outdoor air is filtered prior to delivery to the dwelling unit's occupiable space. An example of MERV 13 filter placement in air handling units is shown in Figure 11-27. Fans may be located in dropped ceiling spaces, mechanical closets, or other spaces dedicated for installation of mechanical equipment. As required in §10-103(b), builders must provide information to building operators and occupants for the operation of any equipment that requires filter replacement.

Figure 11-26: MERV 13 Locations for Ventilation and Space Conditioning Air Handler Unit in Example Scenario



The outdoor air inlet should be located to avoid areas with contaminants such as smoke produced in barbeque areas, products of combustion emitted from gas appliance vents, and vehicle emissions from parking lots or garages. Air may not be drawn from attics or crawlspaces.

To minimize drafts and optimize distribution, supply air can be ducted directly to bedrooms and living areas using an appropriately sized and sealed ventilation-only duct system or by connecting to the HVAC supply plenum. However, distribution of supply air is best practice but not required.

C. Balanced Ventilation

Balanced systems use an exhaust fan and a supply fan to move approximately the same volume of air into and out of the dwelling. To be considered a balanced ventilation system, the total supply airflow and the total exhaust airflow must be within 20 percent of each other. Specifics on measuring airflows to determine compliance are found in RA3.7.4.1.2. Balanced ventilation may be a single packaged unit containing supply and exhaust fans that moves approximately the same airflow, or it may use separate fans. In both cases, air supplied from outdoors must be filtered. (See Section 0: Dwelling Unit Air Filtration for air filter requirements.) Balanced ventilation can incorporate heat recovery. As described in Section 11.4.2.2, heat recovery is required in certain climate zones under the prescriptive path.

§160.2(b)2Aivb requires the whole-dwelling unit ventilation system to either be a balanced system or a supply or exhaust system with compartmentalization testing. The Energy Code encourage the use of balanced ventilation in §160.2(b)2Aiv, since exhaust-only systems bring in air from adjacent spaces, which can negatively impact IAQ.

Some balanced systems are small HRVs or ERVs that are packaged systems. HRVs and ERVs temper incoming air with outgoing air, which reduces the thermal effect of ventilation on heating and cooling loads, but the dual fans increase electrical energy use. HRVs and ERVs are discussed in Section 11.4.2.2.

Like supply ventilation systems, balanced systems are required to be equipped with MERV 13 or better filters to remove particles from the intake airflow prior to delivery to the dwelling unit’s occupiable space per §160.2(b)1.

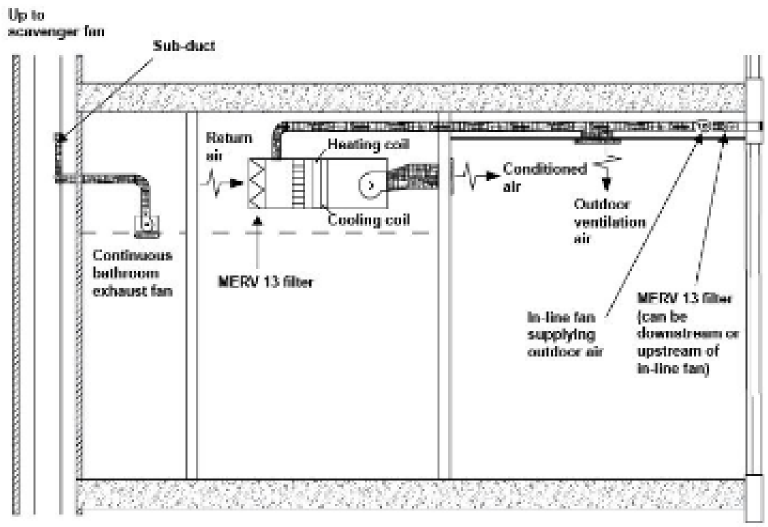
Balanced systems must comply with the same minimum separation distance between intake and exhaust as supply-ventilation systems. The outdoor air inlet should be located to avoid areas with contaminants such as smoke produced in barbeque areas, products of combustion emitted from gas appliance vents, and vehicle emissions from parking lots or garages. Air may not be drawn from attics or crawlspaces.

Balanced ventilation systems may be either unitary (each dwelling unit has own ventilation system) or central systems. Examples of unitary and central balanced systems are provided below.

Unitary Balanced Ventilation

An example of a balanced ventilation system which couples a continuous exhaust fan with an in-line fan that directly supplies outdoor air is shown in Figure 11-28.

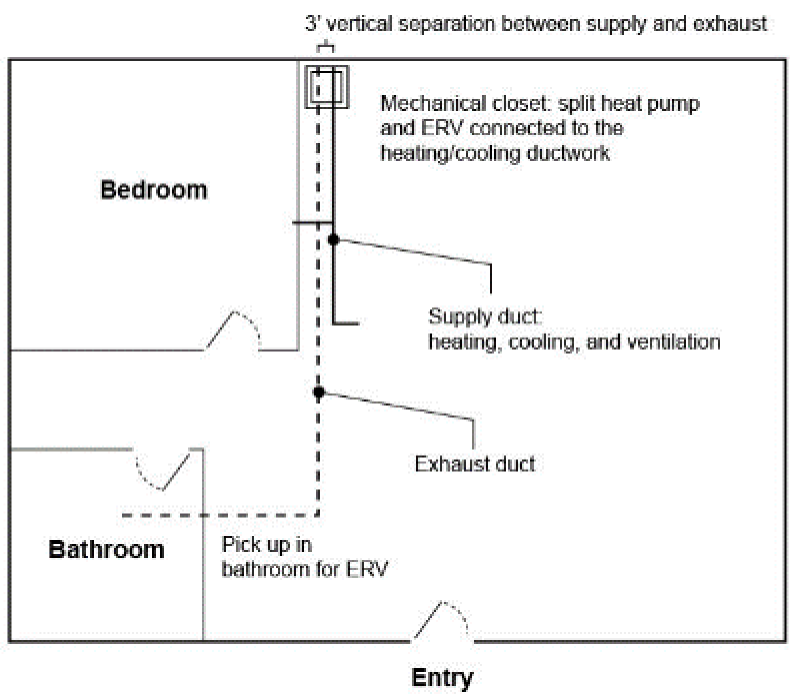
Figure 11-27: Example of Balanced Ventilation Without Heat Recovery: Discrete Supply In-Line Fan with Continuous Bath Exhaust



Strategies other than an inline fan for providing outdoor air include packaged terminal unit (or packaged terminal air conditioning - PTAC) or supply fans.

An ERV or HRV balanced ventilation is shown in Figure 11-29.

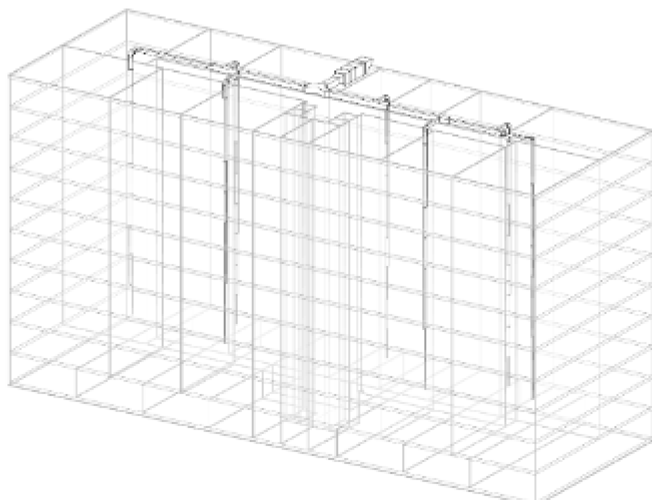
Figure 11-28: Example of Balanced Ventilation with Heat Recovery: Unitary ERV



Central Balanced Ventilation

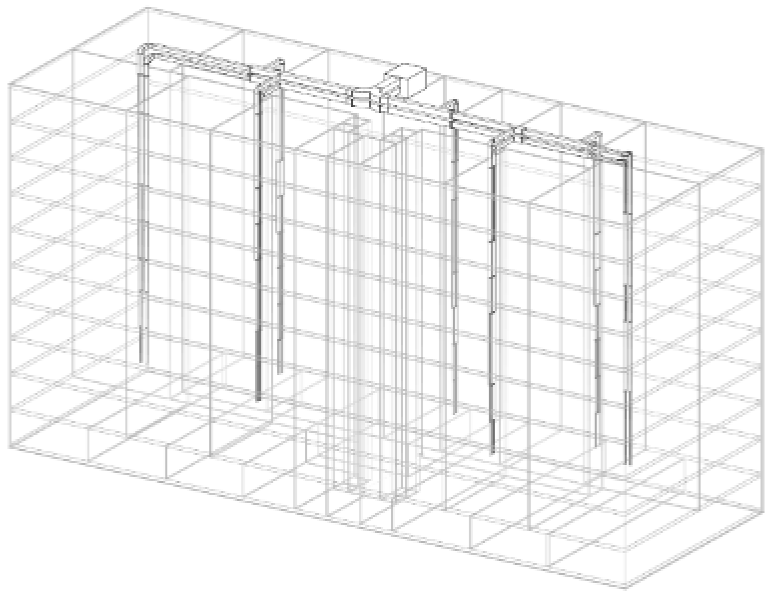
A central balanced ventilation system provides supply-air to and exhaust air from multiple dwelling units. A central balanced ventilation approach could use a dedicated outdoor air system (DOAS) for supplying outdoor air to units and unitary bathroom exhaust. Figure 11-30 shows an example schematic of DOAS; note, the unitary bathroom exhaust is not shown. Because the building in this diagram assumes that the bottom floor is commercial space, the system does not serve this floor.

Figure 11-29: Dedicated Outdoor Air System (DOAS) for Supplying Fresh Air to Dwelling Units



Alternatively, balanced ventilation could be provided by a rooftop HRV or ERV. For the prescriptive path in Climate Zones 1, 2, and 11- 16, the Energy Code require that a central HRV or ERV include a bypass or *free cooling* function that enables the HRV or ERV to bring in fresh air from the outdoors. This function allows incoming air to bypass the heat or energy recovery component when the enthalpy of the outdoor air is within certain temperature and relative humidity limits.

Figure 11-30: Central Balanced Ventilation Strategies: DOAS and Central ERV



As shown in the figures above, each rooftop supply fan, HRV, or ERV would connect (via rooftop ductwork) to vertical shafts. In the example, six vertical shafts serve two dwelling unit from each floor, and one vertical shaft serves one dwelling unit per floor. While not shown in the figure for simplicity, each shaft would need a short horizontal run-out to the dwelling units on each floor and fire smoke dampers (FSDs) at the entry of this duct to the dwelling unit.

Alternatively, central ERVs or HRVs could be located throughout the building (such as one on each floor or for each wing) and serve a cluster of units.

D. Central Fan-Integrated Ventilation

A central fan integrated (CFI) ventilation system is a configuration where the ventilation ductwork is connected to the space conditioning duct system, to enable distribution of ventilation air to the dwelling unit when the space conditioning system air handler is operating. This strategy mixes the outdoor air with the large volume of return air from the dwelling unit before being distributed. CFI ventilation systems consume a relatively high amount of energy compared to the other ventilation types because it uses the air handler fan. The Energy Code includes the following requirements specific to CFI ventilation systems:

1. Continuous Operation is Prohibited – The continuous operation of a space conditioning air handler is prohibited in providing whole-dwelling unit ventilation.

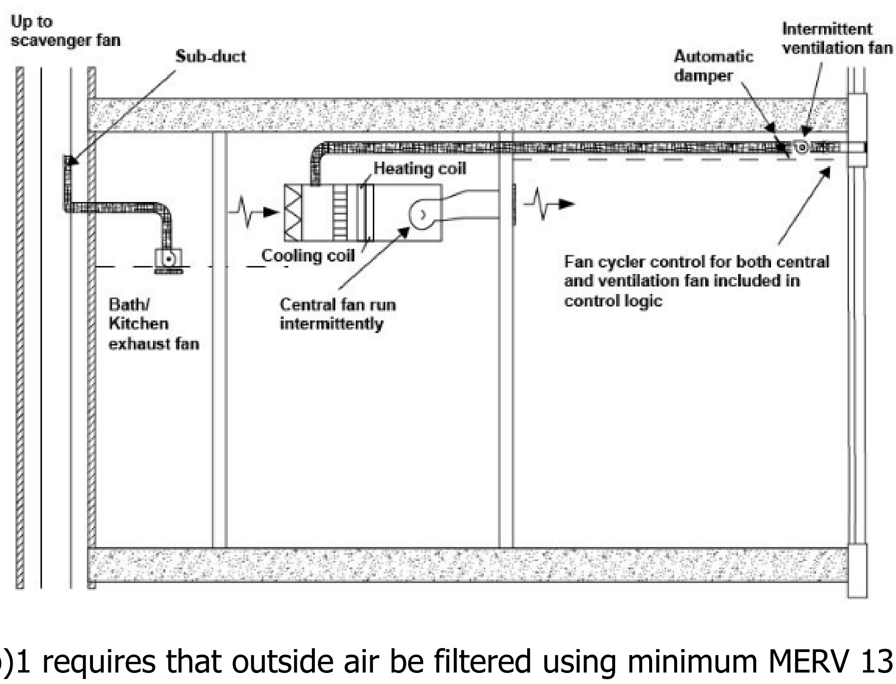
2. Outdoor Air Damper(s) – A motorized damper must be installed on any ventilation duct that connects outdoor air to the space conditioning duct system

and must prevent airflow into or out of the space conditioning duct system when the damper is in the closed position.

3. Damper Control – The outdoor air damper must be controlled to be in the open position only when outdoor air is required for whole-dwelling unit ventilation and must be in the closed position when outdoor air is not required. The damper must be in the closed position when the air handler is not operating. If the outdoor airflow is fan-powered, then the outdoor air fan must not operate when the outdoor air damper is in the closed position.

4. Variable Ventilation Control – CFI ventilation systems must have controls that track outdoor air ventilation run time, and either open or close the motorized damper depending on whether the required whole-dwelling unit ventilation airflow rate is being met. During periods when space conditioning is not called for by the space conditioning thermostat, the controls must operate the air handler fan and the outdoor air damper(s) when necessary to ensure the required whole-dwelling unit ventilation airflow rate is met. This control strategy must be in accordance with ASHRAE 62.2 section 4.5 which requires controls to operate the fan at least once every three hours, and the average whole-dwelling unit ventilation airflow rate over any 3-hour period must be greater than or equal to the required whole-dwelling unit ventilation airflow rate.

Figure 11-31: Example of Central Fan-Integrated (CFI) Ventilation with MERV 13 Filtration



§160.2(b)1 requires that outside air be filtered using minimum MERV 13 particle removal efficiency rated air filters. Filters must be accessible to simplify replacement. For CFI systems, the filters must be installed upstream of the cooling or heating coil; thus, the filter rack provided at the inlet to the air handler may be used. In this case, it is not necessary to provide another MERV 13 or greater filter within the outdoor air duct. Otherwise, filters must be provided at the return grill(s) for the central fan, and another filter must be provided in the outside air ductwork before the point the outside air enters the return plenum of the central fan.

For a CFI ventilation system, both the central forced-air system fan total airflow and the much smaller outdoor ventilation airflow rate must be verified by a HERS Rater.

CFI ventilation systems, devices, and controls may be approved for use for compliance with the HERS field verification requirements for whole-dwelling unit mechanical ventilation in accordance with RA3.7.4.2. CFI ventilation systems are considered intermittent mechanical ventilation systems and must be certified to the Energy Commission that the CFI ventilation system will meet the minimum whole-dwelling unit ventilation requirements.

A listing of certified CFI ventilation systems is posted at the following URL:

http://www.energy.ca.gov/title24/equipment_cert/imv/

The outside air ducts for CFI ventilation systems are not allowed to be sealed/taped off during duct leakage testing. However, CFI outdoor air ductwork that uses controlled motorized dampers that open only when outdoor air ventilation is required and close when outdoor air ventilation is not required may be closed during duct leakage testing.

Because CFI ventilation systems can use a large amount of electricity annually compared to other ventilation system types, the air handlers used in CFI ventilation systems are required to meet the fan watt draw requirements given in Section 150.0(m)13B in all climate zones.

11.4.2.5 Dwelling Unit Ventilation Rate

This section discusses calculation of ventilation rates and necessary ventilation control systems to meet mandatory requirements.

E. Total Ventilation Rate (Q_{tot})

The total ventilation rate Q_{tot} is the volume of ventilation air provided by mechanical ventilation provided from multifamily dwelling units fans, as follows:

$$\boldsymbol{Q_{tot} = 0.03A_{floor} + 7.5(N_{br} + 1)}$$ **Equation 11-1**

Where:

Q_{tot} = total required ventilation rate (CFM)

A_{floor} = conditioned floor area (sq. ft)

N_{br} = number of bedrooms (not less than one)

Dwelling units cannot use a building infiltration credit to reduce the required whole-dwelling unit mechanical ventilation rate, since it is difficult to determine whether that infiltration is truly outdoor air, or it comes from adjacent spaces in the building.

Example 11-13: Dwelling Unit Ventilation Rate Required for Studio

Question

I am building a multifamily dwelling unit that includes 600 sq. ft studios. What is the minimum ventilation rate for the studios?

Answer

Referring to Equation 11-1, the floor area is 600 sq. ft., and the number of bedrooms is assumed to be one (since that is the minimum number of bedrooms allowed for the calculation). The minimum ventilation rate then becomes 0.03 x 600 + 7.5 x (1+1) = 33 CFM

Example 11-14: Dwelling Unit Ventilation Rate Required for 2-bedroom Units

Question

I am building a multifamily dwelling unit that includes 2-bedroom units that are 1,050 sq. ft each. What is the minimum ventilation rate for those units?

Answer

Referring to Equation 11-1, the floor area is 1,050 sq. ft and the number of bedrooms is two. The minimum ventilation rate then becomes 0.03 x 1,050 + 7.5 x (2+1) = 54 CFM

F. Continuous, Scheduled, and Smart Ventilation Systems

Dwelling unit ventilation systems may operate continuously or on a short-term basis. If fan operation is not continuous, the average ventilation rate over any three-hour period must be greater than or equal to the ventilation rate calculated using Equation 11-1.

The Energy Code allows for scheduled ventilation and real-time control. A control method must be chosen so that the relative exposure does not exceed specified peak and average relative exposure limits of ASHRAE Standard 62.2. Normative Appendix C provides direction on calculating the relative exposure and provides standardized calculations for complex ventilation controls implemented by use of digital controls that rely on the manufacturer's product-specific algorithms or software. Users installing any type of intermittent ventilation control system (scheduled or real-time) must submit an application to the Energy Commission to have the control approved. The manufacturers must provide documentation that the system will perform to provide the required whole-dwelling unit mechanical ventilation. Listings of systems approved by the Energy Commission and certified by the manufacturer are located at the following link: www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment-6

Designers should calculate the value for F_{an} as shown in Equation 11-1 and record it on the certificate of compliance. The compliance software approach uses Equation 11-1. in the calculation

Time-of-day timers or duty-cycle timers can be used to control intermittent/variable dwelling unit ventilation. The system must operate automatically without intervention by the occupant. Some controls look back over a set time interval to determine if the CFI system air handler has already operated for heating or cooling before it turns on the air handler for ventilation-only operation.

Example 11-15: Thermostatic Control

Question

Ventilation air is provided whenever the air handler operates via a duct run connecting the return side of the central air handler to the outdoors. The system is estimated to run on calls for heating and cooling about 40% of the time, averaged over the year. If it is assumed that the air handler runs only 25% of the time, and the airflow is sized accordingly, can the system be allowed to run under thermostatic control?

Answer

No. A system under thermostatic control will go through periods with little or no operation when the outdoor temperature is near the indoor set point, or if the system is in setback mode. An intermittently/variably operating ventilation system must be controlled by a timer that will cycle at least once every three hours to assure that adequate ventilation is provided regardless of outdoor conditions. Alternatively, a more complex control may be used if it complies with the requirements in ASHRAE Standard 62.2 Appendix C. These systems must be approved by the Energy Commission before being allowed for use for compliance with the required dwelling unit ventilation.

Cycle timer controls are available that keep track of when (and for how long) the system operates to satisfy heating/cooling requirements in the dwelling unit. These controls turn on the central fan to provide additional ventilation air when heating/cooling operation of the central fan has not already operated for a long enough period to provide the required ventilation. When choosing cycle timer controls for compliance, it is necessary to use models that have been approved by the Energy Commission for use for compliance with whole-dwelling unit mechanical ventilation.

G. Control and Operation

From ASHRAE Standard 62.2, Section 4.4, Control and Operation. A readily accessible manual ON-OFF control, including but not limited to a fan switch or a dedicated branch-circuit overcurrent device, must be provided. Controls must include text or an icon indicating the system's function.

Exception: For multifamily dwelling units, the manual ON-OFF control must not be required to be readily accessible.

From Standards Section 160.2(b)2Aix: Compliance with ASHRAE Standard 62.2 Section 4.4 (Control and Operation) must require manual ON-OFF switches associated with whole-dwelling unit ventilation systems to have a label clearly displaying the following text, or equivalent text: "This switch controls the indoor air quality *ventilation for the home. Leave switch in the "on" position at all times unless the outdoor air quality is very poor."*

While dwelling unit ventilation systems should operate (i.e., be in the ON position) in almost all circumstances, the Energy Code require a manual ON-OFF control, with the purpose of allowing occupants or staff to temporarily turn off the system for extreme events, such as during wildfires. The dwelling unit ventilation system dilutes pollutants that can worsen IAQ such as particulate matter; combustion gases due to imperfect exhaust systems; volatile organic compounds from personal care products, dry cleaning, and other sources; and other pollutants. The dwelling unit ventilation system also reduces relative humidity, which can cause mold or damage the building.

In alignment with ASHRAE Standard 62.2, while the Energy Code require that the manual ON-OFF control be accessible to the occupants in single-family units, there is an exception for multifamily units; it is not required to be readily accessible to the dwelling unit occupants. For multifamily buildings, manual ON-OFF control may be accessible to occupants or only to building maintenance staff. The control strategy where it is only accessible to maintenance staff may be appropriate for multifamily buildings that use central ventilation systems and possibly unbalanced (supply-only or exhaust-only) system types (for which the Energy Code require that all the ventilation systems in the building operate continuously). Continuous operation of all ventilation fans in the building tends to minimize ventilation fan-induced pressure differences between adjoining dwellings, thus, reducing the leakage of transfer air between dwelling units. However, designers should consider the possibility of wildfire smoke or other outdoor air pollution events that could impact the IAQ of dwelling units and ensure there is a means for occupants or maintenance staff to quickly turn off dwelling unit ventilation systems in the circumstances when these systems may inadvertently degrade IAQ. The ventilation system should be returned to the ON position after the extreme event passes.

Example 11-16: Control Options

Question

A bathroom exhaust fan is used to provide dwelling unit ventilation for a dwelling unit. The fan is designed to be operated by a typical wall switch. Is a label on the wall plate necessary to comply with the requirement that controls be "appropriately labeled"?

Answer

Yes. Since the fan is providing the required dwelling unit ventilation, a label is needed to inform the occupant that this switch controls the indoor air quality ventilation for the dwelling unit and directs the occupant to leave it on unless the outdoor air quality is very poor. If the exhaust fan were serving only the local exhaust requirement for the bathroom, then a label would not be required.

11.4.2.6 Dwelling Unit ERV/ HRV Fan Efficacy and Heat Recovery

There is a mandatory requirement that all HRVs and ERVs serving a single dwelling unit must have a fan efficacy of one W/CFM or less. HRVs and ERVs meeting the prescriptive path for multifamily dwelling units using balanced ventilation in Climate Zones 1, 2 and 11-16 must meet more stringent fan efficacy, as described in Section 11.4.2.2.

Fan efficacy is calculated as the Power Consumed in Watts divided by the Net Airflow in CFM. Sensible recovery efficiency is directly reported in the HVI database. If the HVI database or other CEC approved directories do not list the fan energy for the installed model or the proposed product is a large central ERV/HRV whose airflow rate exceeds the maximum listed in the HVI database, use information from the manufacturer's published documentation.

11.4.2.7 Dwelling Unit Local Exhaust

The Energy Code specify local exhaust requirements, but do not adopt ASHRAE Standard 62.2 Section 5 (Local Exhaust). However, the Energy Code are based on the local exhaust requirements in ASHRAE Standard 62.2 Section 5, with the exception of kitchen exhaust. This section provides an overview of demand-controlled local exhaust, continuous local exhaust, and special requirements for kitchen exhaust in the Energy Code. The Energy Code follows the ASHRAE 62.2 definitions for kitchens and bathrooms for these ventilation requirements. Kitchens are any rooms containing cooking appliances, and bathrooms are any rooms containing a bathtub, shower, spa, or other similar source of moisture. A room containing only a toilet is not required to have an exhaust fan; ASHRAE 62.2 assumes there is an adjacent bathroom with local exhaust.

H. Demand Controlled Local Exhaust

Local exhaust (sometimes called spot ventilation) has long been required by building codes and ASHRAE standards for bathrooms and kitchens to remove moisture, odors, and (for kitchens) particulate matter and combustion gases (from gas ranges) at the source.

The Energy Code require bathroom fans with a minimum exhaust airflow of 50 CFM and a sound rating of no more than three sone. To reduce exposure to cooking contaminants, the Energy Code require that kitchen range hoods be capable of exhausting between 110 and 280 CFM depending on dwelling unit size and range type (gas or electric).

Example 11-17: Local Exhaust Required for Toilet

Question

I have dwelling units in my multifamily building with 1½ baths. The half-bath consists of a room with a toilet and sink. Is local exhaust required for the half bath?

Answer

No. Local exhaust is required only for bathrooms, which are defined by the ASHRAE Standard 62.2 as rooms with a bathtub, shower, spa, or some other similar source of moisture. This does not include a toilet or a simple sink for hand-washing.

Example 11-18

Question

The master bath suite in a dwelling unit has a bathroom with a shower and sink. The toilet is in a separate, adjacent room with a full door. Where do I need to install local exhaust fans?

Answer

The standards require local exhaust only in the bathroom, not the separate toilet room.

The Energy Code require that local exhaust fans be designed to be operated by the occupant. This usually means that a wall switch or some other control is readily accessible. There is no requirement to specify where the control or switch needs to be located, but bathroom exhaust fan controls are generally located next to the light switch, and kitchen exhaust fan controls are generally integrated into the range hood or mounted on the wall or counter adjacent to the range hood.

Bathrooms can use a variety of exhaust strategies, including ceiling-mounted exhaust fans or remotely mounted fan ducted to two or more exhaust grilles. Demand-controlled local exhaust can be integrated with the dwelling unit ventilation system to provide both functions.

The control can be a manual switch or automatic control like an occupancy sensor. Some exhaust fans have multiple speeds, and some fan controls have a delay-off function that operates the exhaust fan for a set time after the occupant leaves the bathroom. Title 24, Part 11 (CALGreen) specifies additional requirements for the control and operation of demand-controlled local exhaust. For example, §4.506 requires bathroom exhaust fans to be ENERGY STAR compliant and (unless functioning as a component of a whole house ventilation system) to be controlled with a humidity control.

I. Continuous Local Exhaust

The airflow requirements from ASHRAE Standard 62.2 for continuous exhaust are adopted into the Energy Code and shown in Table 11-23.

Table 11-23: Continuous Local Ventilation Exhaust Airflow Rates (Table 160.2F from the Energy Code)

Application	Airflow
Enclosed Kitchen	5 ACH, based on kitchen volume
Bathroom	20 CFM (10 L/s)

Source: California Energy Commission

The Energy Code allows the designer to install a local exhaust system that operates without occupant intervention continuously and automatically. Continuous local exhaust is generally specified when the local exhaust ventilation system is combined with a continuous dwelling unit ventilation system. For example, if the dwelling unit ventilation is provided by a continuously operating exhaust fan located in the bathroom, this fan may also satisfy the local exhaust requirement for that bathroom, provided the fan provides airflow greater than or equal to the minimum continuous local ventilation airflow rate. Many builders install a two-speed fan that runs at low speed continuously to satisfy the dwelling unit ventilation system requirement, but that can increase to a higher speed to meet the demand-controlled bathroom exhaust requirement using a wall switch. A continuous local exhaust system may also include a *pickup*, which refers to an interior grille that is ducted to a remote fan, which could be ducted to an HRV or ERV.

Continuously operating bathroom fans must operate at a minimum of 20 CFM and a sound rating of no more than one sone. Continuous kitchen exhaust fans must operate at a minimum of five kitchen air changes per hour (ACH).

J. Requirements for Kitchen Exhaust

Kitchen exhaust is important to remove pollution created during cooking processes, including fine particles (PM2.5) and relative humidity; combustion gases such as nitrogen dioxide (NO2) and carbon monoxide (CO) from natural gas and propane-fueled cooktops and ovens; and odors. The most effective method in removing pollutants generated from cooking is to use a vented kitchen range hood, which removes pollutants above the cooking surface before they mix with the air in the rest of the home. The 2022 Energy Code incorporates a new metric for local exhaust called capture efficiency. Capture efficiency is determined in accordance with ASTM E3087 as the fraction of emitted tracer gas that is directly exhausted by a range hood.

The Energy Code allow different options for kitchen exhaust including intermittent (typically demand-controlled) range hoods, a continuously operating fan in the kitchen, or a downdraft fan. For the demand-controlled option, the Energy Code allow the traditional airflow (in cubic feet per minute, or CFM) path for compliance or a capture efficiency path.

Under the Energy Code, dwelling units can use any one of the following options for kitchen exhaust:

- A demand-controlled, vented range hood with at least one setting with a capture efficiency (CE) that meets or exceeds the values shown in Table 11-24.
- A demand-controlled, vented range hood with an airflow that meets or exceeds the exhaust rates shown in Table 11-24.

- A demand-controlled, vented downdraft kitchen exhaust fan (not represented in the table below) in enclosed kitchens with a minimum airflow of 300 cfm or a capacity of 5 air changes per hour. In a nonenclosed kitchen, the fan must have a minimum airflow of 300 cfm (no air changes per hour option).
- For enclosed kitchens only: Continuous exhaust system with a minimum airflow equal to five kitchen air changes per hour.

Table 11-24: Kitchen Range Hood Airflow Rates (CFM) and ASTM E3087 Capture Efficiency (CE) Ratings According to Dwelling Unit Floor Area and Kitchen Range Fuel Type

Dwelling Unit Floor Area (sq. ft)	Hood Over Electric Range	Hood Over Natural Gas Range
>1500	50% CE or 110 CFM	70% CE or 180 CFM
>1000 - 1500	50% CE or 110 CFM	80% CE or 250 CFM
750-1000	55% CE or 130 CFM	85% CE or 280 CFM
<750	65% CE or 160 CFM	85% CE or 280 CFM

Source: from Table 160.2-G in the Energy Code

The capture efficiency path (Option 1) is specific to the Energy Code. The minimum capture efficiency or airflow requirement for the range hood is the minimum required to adequately capture the moisture, particulates, and other products of cooking and/or combustion. While many products do not have published capture efficiency results as of the time of the publication of this manual, Option 1 is intended to be a forward-looking approach and will support future listings.

While capture efficiency is the metric that directly measures pollutant removal, the airflow path (Option 2) is provided because capture efficiency generally increases with airflow, and the HVI and AHAM databases list airflow for kitchen exhaust appliances. ASHRAE Standard 62.2 includes a similar path as Option 2, but with lower required airflows (minimum 100 CFM). Because there is less air available for dilution in small dwelling units, the Energy Code set higher minimum requirements for smaller dwelling units. Because gas ranges emit NO2 and CO, in addition to the PM2.5 released from cooking processes, the capture efficiency and airflow requirements are higher for hoods over gas ranges.

The vented downdraft compliance option (Option 3) and continuous kitchen exhaust option (Option 4) are taken directly from ASHRAE Standard 62.2. The definition of an "enclosed kitchen", which must be met to use continuous kitchen exhaust, is also taken from ASHRAE Standard 62.2, and is defined as "permanent openings to interior adjacent spaces do not exceed a total of 60 square feet". Only in enclosed kitchens, the exhaust requirement can also be met with either a ceiling or wall-mounted exhaust fan or with a ducted fan or ducted ventilation system that can provide at least five air changes of the kitchen volume per hour.

Recirculating range hoods that do not exhaust pollutants to the outside cannot be used to meet the Energy Code requirements, unless paired with an exhaust system exhausting to the outside that can provide at least one of the following:

1. Continuous or demand-controlled operation in an enclosed kitchen providing five air changes of the kitchen volume per hour, or
2. Demand-controlled operation in an enclosed or unenclosed kitchen providing at least 300 cfm of exhaust.

Generally, HRV/ERV manufacturers do not recommend that kitchen exhaust pass through HRV or ERV equipment, because the heat, moisture, grease, and particulates could damage heat exchange core.

The Energy Code do not explicitly specify a static pressure at which range hoods should be measured for airflow. However, the Energy Code require that range hoods be listed in the HVI or AHAM product directories, and both of those directories list range hood airflows at 0.1" w.c. (and some at 0.25" w.c.), since 0.1" is the basic rating point for range hoods in HVI Standard 920. Note that some product airflows are listed at working-speed at lower static pressures, but working-speed airflows can only be used for compliance with the sound requirement, not airflow requirement.

Example 11-19: Continuous Kitchen Exhaust Solution

Question

I'm building a multifamily building project where the kitchen is partially enclosed. There's a bedroom along one wall, but the kitchen is open to the rest of the living area by a 7 ft wide by 8 ft tall opening. I'd like to use continuous kitchen exhaust, which can double for dwelling unit ventilation. Is that allowable?

Answer:

The definition of an enclosed kitchen is one whose permanent openings to interior adjacent spaces do not exceed a total of 60 sq. ft. At 8 ft x 7 ft = 56 sq. ft, your kitchen just meets that definition, so you could use continuous kitchen exhaust. Dwelling unit ventilation needs heat or energy recovery if the project is in climate zones 1, 2, or 12-16. We would not recommend ducting kitchen exhaust to the ERV or HRV, given the HRV/ERV manufacturer restrictions.

The Energy Code require either field-measurement of kitchen exhaust airflow or meeting prescriptive duct sizing requirements. When complying using prescriptive duct sizing requirements, the Energy Code require range hood airflow at a static pressure of 0.25" of w.c. Section 11.4.4.3 Duct Sizing provides more detail.

The Energy Code require verification that range hoods are HVI- or AHAM-certified to provide at least one speed setting at which they can deliver at least 100 CFM at a sound level of 3 sones or less. (This rating point of 100 CFM is lower than the minimum air flow required for pollutant removal.) Verification must be in accordance with the procedures in *Reference Residential Appendix* RA3.7.4.3. Range hoods that have a minimum airflow setting exceeding 400 CFM are exempt from the sound requirement. HVI listings are available at: https://www.hvi.org/hvi-certified-products-directory. AHAM listings are available at: https://www.aham.org/AHAM/What_We_Do/Kitchen_Range_Hood_Certification.

The Energy Code limits exhaust airflow when atmospherically vented combustion appliances are located inside the pressure boundary. The demand-controlled range hood airflow and capture efficiency requirements will often exceed this exhaust airflow limit for typical multifamily dwelling units. Therefore, most multifamily dwelling unit with atmospherically vented appliances will need a makeup air fan. Refer to Section 11.4.5.3 for more information.

Example 11-20: Ceiling or Wall Exhaust vs Demand-Controlled Range Hood in an Enclosed Kitchen

Question

I am building a multifamily building, where each unit has an enclosed kitchen that is 12 ft. x 14 ft. with a 10 ft. ceiling. What size ceiling exhaust fan or range hood fan is required if I want to use continuous ventilation? What about if I use a demand-controlled range hood? The units are a mix of sizes but include 800, 1025, and 1200 sq. ft units. We are planning to use natural gas ranges.

Answer

If a range hood exhaust is not used, either 300 CFM or 5 kitchen ACH minimum airflow is required. The kitchen volume is 12 ft. x 14 ft. x 10 ft. = 1,680 ft^3. Five air changes are a flow rate of 1,680 ft^3 x 5/ hr. ÷ 60 min/hr. = 140 CFM. So, this kitchen must have a ceiling or wall exhaust fan of 140 CFM if you want to use the continuous exhaust approach. That would end up consuming significant energy, so we would not recommend it.

We would recommend you install a demand-controlled range hood instead. The minimum flow rate depends on the size of the units. If all units have natural gas ranges, the minimum flow rate would be 280 CFM for the 800 sq. ft units, and 250 CFM for the 1025 and 1200 sq. ft units. If you installed electric ranges (induction or resistance types), the minimum flow rate would be 130 cfm for the 800 sq. ft. units, and 110 cfm for the 1,025 and 1,200 sq. ft units.

The verification protocol for kitchen exhaust systems remains the same compared with the 2019 Energy Code procedures. The only difference is that an option of using capture efficiency (instead of airflow) has been added to verify the kitchen exhaust system.

- Manufacturers must test the range hood air flow and/or capture efficiency, which will be available in the HVI or AHAM database to reference for verification.
- Kitchen exhaust systems are required to be verified by a HERS Rater or ATT, depending upon the number of habitable stories in the building. The verification protocol requires comparing the installed model to ratings in the HVI or AHAM directory of certified ventilation products to confirm the installed range hood is rated to meet the required capture efficiency or airflow in the Energy Code. The HERS rater or ATT should also confirm the range hood meets the sound requirements specified in the Energy Code.

11.4.2.8 Dwelling Unit Ventilation Airflow Measurement

K. Whole-dwelling Unit Ventilation System

§160.2(b)2Avii requires airflow measurement of the whole-dwelling unit ventilation system. The purpose is to ensure that the specified ventilation rate is delivered to the unit.

All whole-dwelling unit ventilation systems must demonstrate compliance by direct airflow measurement using a flow hood (such as shown in Figure 11-33), flow grid, or other approved measuring device. HERS verification of whole-dwelling unit ventilation airflow is required for newly constructed buildings and existing buildings with additions greater than 1,000 sq. ft or an increase in the number of dwelling units.

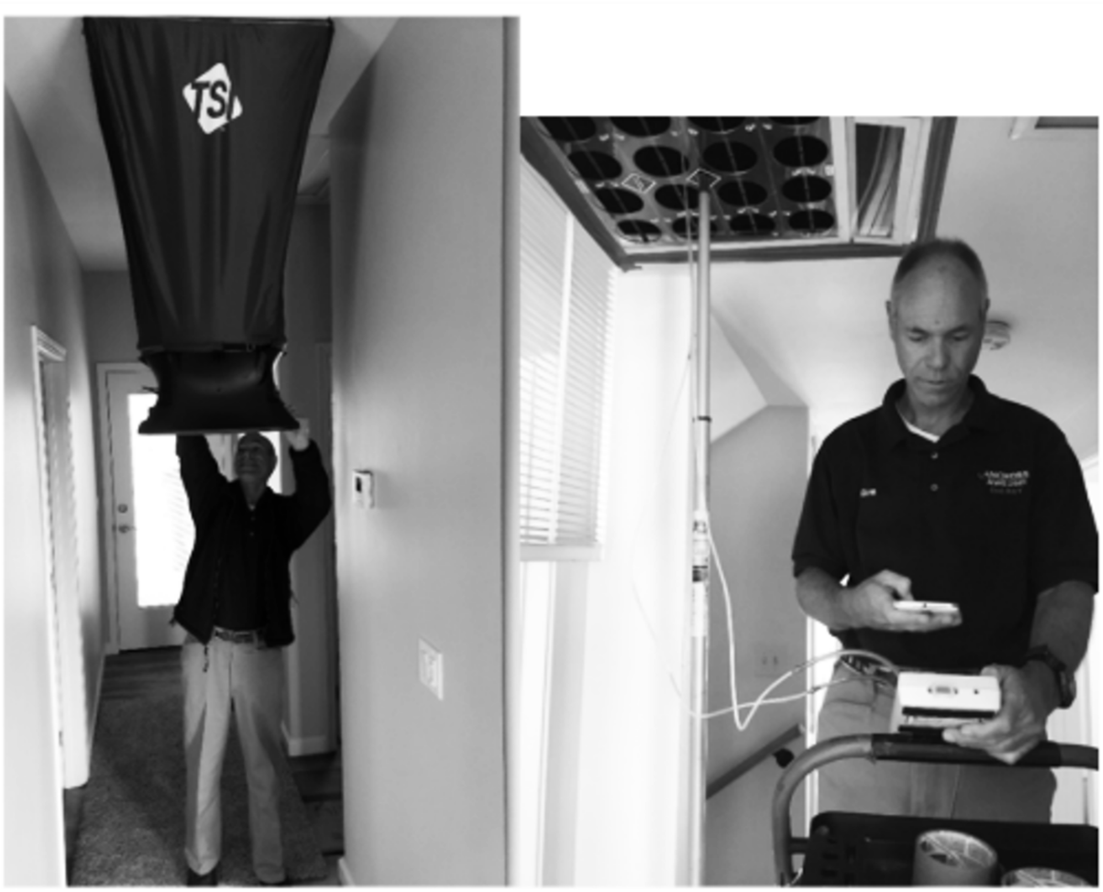
Residential Appendix RA3.7.4 (for multifamily buildings up to three habitable stories) and Nonresidential Appendix NA2.2.4.1.1 (for multifamily buildings four or more habitable stories) provide guidance for measurement of supply, exhaust, and balanced system types. These measurement procedures are applicable when there is a fixed airflow rate required for compliance, such as for systems that operate continuously at a specific airflow rate or systems that operate intermittently at a fixed speed (averaged over any three-hour period), according to a fixed programmed pattern that is verifiable by a HERS Rater on site. (Refer to ASHRAE Standard 62.2 Section 4.5.1 Short Term Average Ventilation.)

For exhaust-only systems, measurement of the whole-dwelling unit ventilation airflow should be done by measuring airflow of the exhaust fan(s). While this approach will over-represent the airflow from the outdoors, it is difficult to determine the fraction of the infiltration from the outdoors versus adjacent spaces in the building.

For whole-dwelling unit ventilation systems that use scheduled ventilation or real-time controls, the Energy Commission may consider the ventilation system for approval, if the manufacturer provides a method that can be used by a

HERS Rater or ATT to verify that an installed system is operating as designed. Figure 11-33 shows examples of an airflow rate measuring devices.

Figure 11-32: System Airflow Rate Measurement Using Flow Capture Equipment



Source: California Statewide CASE Team

11.4.2.9 Local Exhaust System

Local exhaust systems also require airflow measurement, similar to the whole-dwelling unit ventilation system. For local exhaust systems, there are two ways to demonstrate compliance with airflow requirements of §160.2(b)2Avie:

- Test the ventilation system using an airflow measuring device after completion of the installation to confirm that the delivered ventilation airflow meets the requirement using same process as airflow measurement of whole-dwelling unit ventilation system.
- Use a fan that has a certified airflow rating that meets or exceeds the required ventilation airflow, and ventilation ducts that meet either the fan manufacturer's published duct design specifications or the duct design requirements given in Table 11-25.

11.4.2.10 Dwelling Unit Air Filtration

Air filtration is used in forced air systems to protect the equipment from dust accumulation that could reduce the capacity or efficiency of the system. Preventing dust buildup may also prevent the system from becoming a host to biological contaminants such as mold, especially if dust is deposited on cooling coils that become wet from water condensation during comfort cooling operation. Air filter efficiencies of Minimum Efficiency Reporting Value (MERV) 6 remove approximately half of PM10 (Particulate Matter 10 microns or smaller), which includes these large airborne dust particles.

Air filter efficiencies of at least MERV 13 are needed to protect occupants from exposure to the smaller airborne particles that are known to adversely affect health. These smaller particles are often referred to as PM 2.5 which refers to particulate matter of 2.5 microns or smaller. PM2.5 can travel into the lungs and bloodstream, causing respiratory and cardiovascular impacts. PM2.5 is produced from several sources including combustion from cooking and exhaust from motor vehicles that enters a dwelling through ventilation openings and infiltration.

§160.2(b)1 requires that all recirculated air or outdoor air supplied to the occupiable space is filtered with MERV 13 filtration prior to being supplied to the occupiable space. The requirement applies to all ventilation systems with supply-side ventilation, including supply-only systems, ERVs, HRVs, and the supply side of other balanced systems with ductwork greater than 10 feet. This requirement does not apply to exhaust-only ventilation systems since those systems do not have dedicated supply air. However, since §160.2(b)1 applies to both recirculated and outdoor air, a dwelling unit with an exhaust-only ventilation system and forced air furnace will still need MERV 13 filtration in the furnace air handling unit with ductwork greater than 10 feet in length.

§160.2(b)1 also imposes air filtration requirements to address pressure drop and ensure minimum delivered airflow. These are detailed in Section 11.6.4.10.

Any gaps around an air filter allows air to bypass the filter. The Energy Code requires that filter racks and grilles use gaskets, sealing, or other means to close gaps around inserted filters and prevent air from bypassing the filter. Filter racks and grilles include any device that houses the air filter used to satisfy the air filtration requirements.

11.4.2.11 Dwelling Unit Compartmentalization, Adjacent Spaces and Transfer Air

Compartmentalization (i.e., sealing of the dwelling unit air barrier) is important for maintaining the indoor air quality of multifamily dwelling units because it limits transfer air. Transfer air is the airflow between adjacent dwelling units or between a dwelling unit and other nearby spaces (e.g., garage or crawlspace) in a multifamily building, that can be a major contributor to poor IAQ in the dwelling units. Transfer airflow is caused by differences in pressure between adjacent spaces that force air to flow through leaks in the dwelling unit enclosure. The pressure differences may be due to stack effects (hot air rising in taller buildings when outside air temperature is low, leading to air pressing upward and exiting the building through upper floors) and wind effects, but unbalanced mechanical ventilation is also a contributor. Compartmentalization minimizes leaks in all the dwelling enclosures in the building to prevent pollutants such as tobacco smoke, pollution generated from food preparation in the kitchen, odors, and other pollutants from being transferred to adjacent dwellings in the building. Drawing ventilation air from the garage could introduce carbon monoxide or volatile organic compounds into the indoor air. Drawing ventilation air from an unconditioned crawlspace could cause elevated allergen concentrations in the dwelling. In addition to maintaining good IAQ, compartmentalization provides energy benefits, by reducing leakage of conditioned air to the exterior.

The Energy Code in §160.2(b)2Aiv provide two compliance paths for mandatory mechanical ventilation which improve indoor air quality in multifamily buildings:

- Install a balanced ventilation system for all dwelling units.
- Compartmentalize each dwelling unit by sealing each dwelling unit envelope and verify that the dwelling unit leakage is not greater than 0.3 CFM per sq. ft of dwelling unit enclosure area using the procedures in RA3.8 (blower door test for multifamily buildings with up to three habitable stories) or NA2.3 (blower door test for multifamily buildings with four or more habitable stories) as applicable.[3] Sampling is allowed for the blower door testing, according to RA2.6 and NA1.6. If the sampled dwelling units in the multifamily building pass this blower door test, use of continuously operating supply-only ventilation systems, or continuously operating exhaust-only ventilation systems is allowed.

If the balanced ventilation path (#1) is used, air sealing to 0.3 CFM per sq. ft and blower door testing is not required. Both balanced ventilation and compartmentalization provide IAQ benefits. Balanced ventilation ensures that outdoor air is provided at the required rates, and compartmentalization reduces pollutant transfer between dwelling units. If compartmentalization (#2) is used, air sealing and blower door testing must be conducted. Note the Energy Code deviates from ASHRAE Standard 62.2, which requires compartmentalization in multifamily dwelling units, but does not require balanced ventilation as a mandatory requirement.

To compartmentalize the unit, project teams should seal areas that include, but are not limited to the following:

- Vent and pipe penetrations, including those from water piping, drain waste and vent piping
- HVAC piping and sprinkler heads

[3] While multifamily buildings up to three habitable stories follow the procedures in the Residential Appendix and multifamily buildings four or more habitable stories follow the procedures in the nonresidential appendix, for the blower door test, RA3.8 and NA2.3 provide the same protocol. In other words, this test is the same regardless of the number of stories.

- Electrical penetrations, including those for receptacles, lighting, communications wiring, and smoke alarms
- HVAC penetrations, including those for fans and for exhaust, supply, transfer, and return air ducts

In addition, project teams should seal leaks and gaps in the dwelling-unit air barrier, including but not limited to the intersections of baseboard trim and floor, the intersections of walls and ceilings, around window trim and dwelling-unit doors, and the termination points of internal chases in attics, between floors, and crawlspaces.

11.4.2.12 Dwelling Unit Prescriptive Requirements

A. Balanced Ventilation

§170.2(c)3

If a balanced system is used to satisfy mandatory requirements, the prescriptive requirements of §170.2(c)3Biv requires multifamily units to install HRVs or ERVs in Climate Zones 1, 2, and 11-16. Multifamily units that do not trigger this requirement may still choose to use an HRV or ERV.

For multifamily buildings up to three stories in Climate Zones 4-10, balanced ventilation systems without heat or energy recovery are required by §170.2(c)3 to have a fan efficacy of 0.4 W/CFM or less. For example, if the balanced ventilation system includes a bathroom exhaust fan and an in-line supply fan, the total rated fan efficacy must be less than 0.4 W/CFM. The total fan efficiency for the ventilation system is calculated using the parameters in the following equation.

$$\text{Total fan efficiency} = \frac{Total\ rated\ power\ of\ exhaust\ and\ supply\ fan\ at\ ventilation\ flow\ rate\ (W)}{\text{Outdoor air ventilation flow rate }(cfm)}$$

Compliance with the fan efficiency requirements for ventilation can be verified by reviewing product certification data from the HVI database or the AHAM Certified Range Hood Directory. Linear interpolation of rated performance parameters may be used when calculating the fan efficacy at the required outdoor airflow rate as described in Reference Residential Appendix RA3.7.4.4. The HVI database can be found at the following link: www.hvi.org/hvi-certified-products-directory. The AHAM Directory can be found at the following link: https://www.aham.org/AHAM/What_We_Do/Kitchen_Range_Hood_Certification.

B. CFI Ventilation Systems Fan Watt Draw

§170.2(c)3Biii

When using the prescriptive approach, the fan efficacy of CFI systems must be verified by a HERS Rater (for multifamily dwelling units in buildings up to three habitable stories) or an ATT (for multifamily dwelling units in buildings four or more habitable stories) using the same methods as required for furnaces and air handlers. (See

Reference Residential Appendix RA3.3.) For verification, the central system air handler must be operating in ventilation mode with the outdoor air damper open and with outdoor ventilation air flowing into the return plenum from the supply duct. Furthermore, the airflow that must be measured is the total airflow through the air handler (system airflow), which is the sum of the return airflow, and the outside air ducted to the return plenum (ventilation airflow).

The watt draw must be less than or equal to 0.45 W/CFM for furnaces, 0.58 W/CFM for air handlers that are not gas furnaces, and 0.62 W/CFM for small duct, high-velocity systems. If not, the performance approach must be used.

C. ERV/HRV Fan Efficacy and Heat Recovery

§170.2(c)3Biv, §170.2(c)4A

For Climate Zones 1, 2, and 11-16, in addition to requiring heat recovery for ventilation, the prescriptive requirements require that HRVs and ERVs serving a single dwelling unit must have a fan efficacy of 0.6 W/CFM or less per §170.2(c)3Biv.

Central ERVs or HRVs (serving multiple dwelling units) must meet fan efficacy requirements per §170.2(c)4A using the fan power allowance formula below. For ERVs and HRVs, the fan power allowance must be separately calculated for the supply and return airflows, and then summed.

$$FPA_{adj} = \frac{Q_{comp}}{Q_{sys}} \times FPA_{comp}$$

Where:

- FPA_{adj} = The corrected fan power allowance for component in W/CFM
- Q_{comp} = The airflow through component in CFM
- Q_{sys} = The system airflow
- FPA_{comp} = The fan power allowance of the component from Table 170.2-B or Table 170.2-C.

ERVs and HRVs meeting the §170.2(c)3Biv prescriptive requirements must also meet a minimum sensible recovery efficiency or effectiveness of 67%, rated at 32°F.

Compliance with the requirements for unitary equipment can be verified by reviewing product certification data from the HVI database at the URL below. See Reference Residential Appendix RA3.7.4.4 for more information on verification of unitary equipment performance parameters.

https://www.hvi.org/hvi-certified-products-directory

Central equipment must have a bypass function for free cooling, in which the incoming outdoor air bypasses the heat exchanger when the outdoor air temperature is below the cooling set point. This allows the ventilation system to operate in economizing mode taking advantage of cool outdoor temperatures. The bypass mode is an important feature, particularly in mild climates where heat recovery without bypass can increase cooling loads. The controls must meet the air economizer high limit shut off control requirements in Table 170.2-G.

For ERVs or HRVs that are not meeting the prescriptive requirements, including in Climate Zones 3-10, the fan efficacy need only meet the mandatory requirement of 1.0 W/CFM or less.

11.4.2.13 Dwelling Unit Performance Approach

B. Ventilation Systems without Heat Recovery

The performance approach allows the option of default minimum dwelling unit ventilation airflow rate and a watt draw value of 0.25 W/CFM, which is typical of continuous exhaust fans that meet the 1 sone requirement. If the installed fan has a different airflow and fan efficacy, the actual airflow rate and fan watt draw of the fan must be used.

Values for airflow and fan W/CFM information may be available from the HVI directory at the following link: www.hvi.org/hvi-certified-products-directory/.

If HVI does not list fan energy for the installed model, use information from the manufacturer's published documentation. Note that fan energy may sometimes be listed as CFM/W rather than W/CFM, so must be converted to the Energy Code' fan efficacy units of W/CFM. Installation of a dwelling unit ventilation system with a fan watt draw greater than 1.2 W/CFM of ventilation airflow will increase the proposed design energy. Values less than 1.2 W/CFM are compliance-neutral (standard design = proposed design).

11.4.2.14 ERV/HRV Fan Efficacy and Heat Recovery

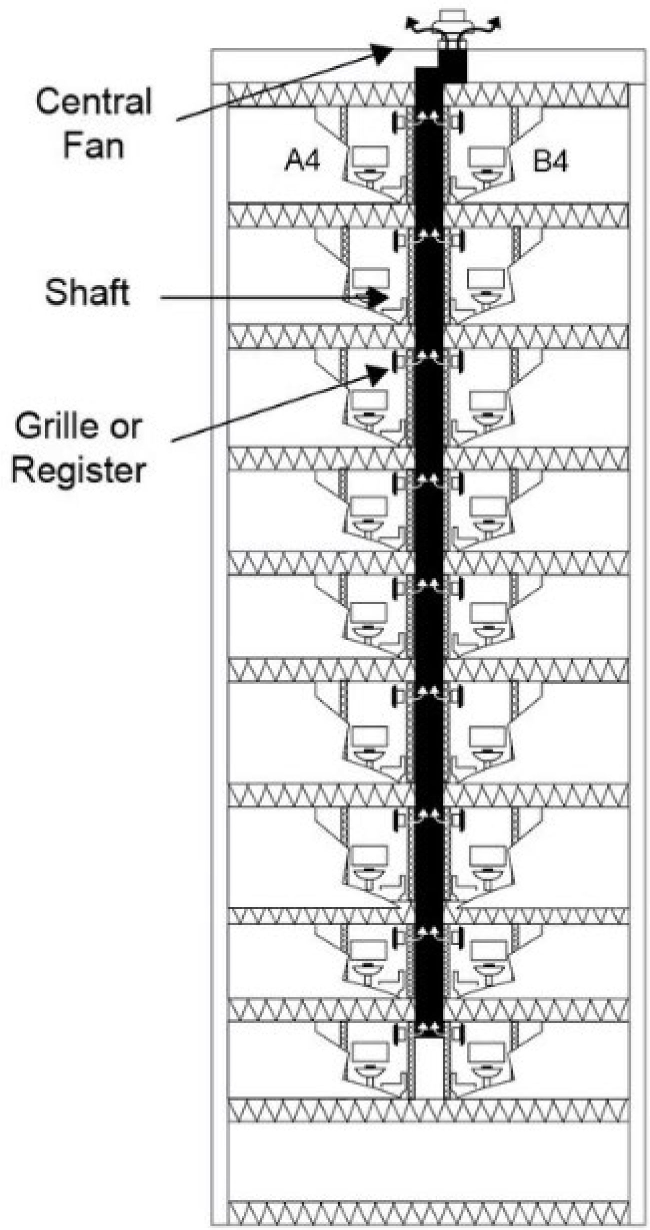
For the performance approach, the proposed equipment recovery efficiency, fan efficacy, and bypass condition are used in the compliance software. The compliance software assumes values for the standard design that align with the prescriptive requirements for ERVs/HRVs.

11.4.3 Central Ventilation Duct Systems Serving Dwelling Units

Central ventilation systems serving multiple dwelling units are often used, particularly in tall buildings, to provide supply air (such as in a DOAS system), exhaust, or balanced ventilation (such as a central ERV or HRV). These systems reduce the number of fans that must be maintained and the number of envelope penetrations for supply intakes or exhaust discharges.

The central ventilation system is typically comprised of a central fan (often located at the rooftop), a central ventilation duct (shaft) that runs between floors, horizontal branches to connect the dwelling units to the shaft, and in-unit connection points such as grilles to deliver (for supply) or remove (for exhaust) air from each dwelling unit. Figure 11-33 illustrates an example with no horizontal branches.

Figure 11-33: Diagram of Central Exhaust Ventilation Duct System Components



Source: Center for Energy and Environment 2016

11.4.3.1 Central Ventilation Mandatory Requirements

When a supply or exhaust system provides dwelling unit ventilation to more than one dwelling unit, the airflows in each dwelling unit must be equal to or greater than the specified ventilation rate, and the airflows for each dwelling unit must also be balanced to be no more than 20% greater than the specified rate, per §160.2(b)2Av. The specified rate for the systems that share a common fan/shaft may be the minimum rate required for compliance, in which case each of the dwellings receiving airflow from a common fan/shaft must have ventilation airflow no more than 20% greater than the minimum dwelling unit ventilation airflow required. If the lowest airflow provided to any of the dwellings served by the common fan/shaft is a specific percent value greater than the minimum required for compliance, then each of the dwellings receiving airflow from that common fan/shaft must have ventilation airflow no more than 20% greater than that lowest dwelling unit ventilation airflow. For example, if the lowest ventilation airflow among all dwellings served by the common fan/shaft is 2% greater than the minimum required for compliance, then all dwellings served by the common fan/shaft must be balanced to have ventilation airflow that is no more than 22% greater than the minimum ventilation airflow required for compliance

These systems must use balancing devices to ensure the dwelling-unit airflows can be adjusted to meet this balancing requirement. These system balancing devices may include, but are not limited to, constant air-regulation devices (often referred to as "CAR dampers"), orifice plates, and variable-speed central fans.

In addition, for multifamily buildings with four or more habitable stories, the Energy Code include a mandatory sealing and leakage testing requirement for central ventilation systems providing continuous airflow or an airflow to meet the balanced ventilation path in §160.2(b)2Aiv. An ATT must conduct a fan pressurization test to show that central shaft leakage is no greater than 6% compared to a nominal airflow rate of the central fan at 0.2 inches water column (inch w.c.) (50 Pa) for ducts serving more than six dwelling units. For ducts serving six or fewer dwelling units, the maximum leakage is the same, but the test must be conducted at 0.1 inches w.c. (25 Pa), since these systems typically have a lower operating pressure. As described in the NA1.6 procedures, sampling may be used for this duct testing requirement, and the ATT may conduct the leakage test at rough-in. Central ventilation systems providing intermittent flows, such as demand-controlled exhaust from kitchens, bathrooms, or driers, are exempt from this testing requirement, although careful sealing is still recommended.

The airflow, sealing, and leakage testing requirements work in tandem to provide better control of airflow to each unit so that units are not overventilated (which would waste energy) or under-ventilated (which would degrade IAQ).

11.4.4 Air-Moving Equipment - Mandatory Requirements (Section 7 of ASHRAE Standard 62.2)

From ASHRAE Standard 62.2, Section 7.1, Selection and Installation.

Ventilation devices and equipment serving individual dwelling units must be tested in accordance with ANSI/ASHRAE Standard 51/AMCA 210, Laboratory Methods of Testing Fans for Aerodynamic Performance Rating, and ANSI/AMCA Standard 300, Reverberant Room Method for Sound Testing of Fans, and rated in accordance with the airflow and sound rating procedures of the HVI (HVI 915, Loudness Testing and Rating Procedure; HVI 916, Air Flow Test Procedure; and HVI

920, Product Performance Certification Procedure Including Verification and Challenge). Installations of systems or equipment must be carried out in accordance with manufacturers' design requirements and installation instructions.

Equipment used to meet the dwelling unit ventilation requirements or the local exhaust ventilation requirements must have been tested and rated by manufacturers to ensure that the equipment meets the requirements of this section.

11.4.4.1 Fan Selection and Installation

The Energy Code require that equipment used to comply with the standard be selected based on tested and certified ratings of performance for airflow and sound. The HVI and AHAM products directories list certified ratings of performance for airflow and sound. The directories can be used to verify compliance with Energy Code requirements. The *HVI-Certified Products Directory* can be viewed at the following link: www.hvi.org/hvi-certified-products-directory.

The AHAM-Certified Products Directory can be viewed at the following link: www.aham.org/AHAM/What_We_Do/Kitchen_Range_Hood_Certification.

In addition, the Energy Code require that the fans be installed in accordance with the manufacturer's instructions.

11.4.4.2 Fan Sound Ratings

From ASHRAE Standard 62.2, Section 7.2, Sound Ratings for Fans.

Ventilation fans must be rated for sound at no less than the minimum airflow rate required by this standard as noted below. These sound ratings must be at a minimum of 0.1 in. w.c. (25 Pa) static pressure in accordance with the HVI procedures referenced in Section 7.1.

Exception: HVAC air handlers and remote mounted fans need not meet sound requirements. To be considered for this exception, a remote mounted fan must be mounted outside the habitable spaces, bathrooms, toilets, and hallways, and there must be at least 4 ft (1 m) of ductwork between the fan and the intake grille.

7.2.1 Dwelling-Unit Ventilation or Continuous Local Exhaust Fans. These fans must be rated for sound at a maximum of 1.0 sone.

7.2.2 Demand-Controlled Local Exhaust Fans. Bathroom exhaust fans used to comply with Section 5.2 must be rated for sound at a maximum of 3 sones. Kitchen exhaust fans used to comply with Section 5.2 must be rated for sound at a maximum of 3 sones at one or more airflow settings greater than or equal to 100 CFM (47 L/s).

Exception: Fans with a minimum airflow setting exceeding 400 CFM (189 L/s) need not comply.

Dwelling unit occupants may choose not to operate ventilation equipment, particularly local exhaust fans, due to the noise the fans may create. To address this, the Energy Code require that certain fans be rated for sound, and installed fans must have ratings below specified limits.

§160.2(b)2Avif requires kitchen range hoods to be rated for sound in accordance with Section 7.2 of ASHRAE Standard 62.2, and it provides an exception to allow kitchen range hoods to be rated for sound at a static pressure determined at working speed as specified in HVI 916 Section 7.2. The static pressure at working speed may be lower than 0.1 inch w.c.

Because of the variables in length and type of duct and grille, there is no clearly repeatable way to specify a sound level for ventilation devices that are not mounted in the ceiling or wall surface. Consequently, air handlers and remote fans are exempted from the sound rating requirements that apply to surface-mounted fans. However, to reduce the amount of fan and/or motor noise that could come down the duct to the grille, the Energy Code sets a minimum of four ft. of ductwork between the grille and the ventilation device. This may still produce an undesirable amount of noise for the occupant, especially if hard metal duct is used. A sound attenuator will reduce the transmitted sound into the space.

C. *Continuous Ventilation Fans (Surface-Mounted Fans)*

Continuously operated fans must be rated at 1 sone or less. This 1 sone requirement applies to continuous dwelling unit ventilation fans and to continuous local exhaust ventilation fans.

D. *Intermittent/Variable or Demand Controlled Fans (Surface-Mounted Fans)*

Intermittently/variably operated dwelling unit ventilation fans must be rated at 1 sone or less. Demand-controlled local exhaust fans must be rated at a maximum of 3 sones unless the minimum rated airflow is greater than 400 CFM.

The Energy Code extend the fan sound requirements to include range hoods and bath exhaust fans. Dwelling unit ventilation fans or systems that operate continuously must be rated 1 sone or less. Demand-controlled local exhaust fans, including demand-controlled bathroom fans, must be 3 sones or less. Range hood exhaust fans must also be rated at 3 sones or less at a minimum required speed of 100 CFM.

The 3 sone requirement is measured at a minimum required speed of 100 CFM that is different from the minimum airflow requirements of the Energy Code for kitchen range hoods. The Energy Code require range hoods to have a minimum airflow between 110 CFM and 280 CFM when using airflow rating for compliance, dependent on the size of the dwelling unit and kitchen fuel used. The requirements for the minimum airflow for a sound rating and the minimum airflow for an airflow rating are different to allow sound ratings of previously tested range hoods to be used. The Energy Code previously permitted testing at “working speed”.

11.4.4.3 Duct Sizing

For local exhaust systems, there are two ways to demonstrate compliance with airflow requirements of §160.2(b)2Avie:

- Test the ventilation system using an airflow measuring device after completion of the installation to confirm that the delivered ventilation airflow meets the requirement discussed in Section 11.4.2.1.
- Use a fan that has a certified airflow rating that meets or exceeds the required ventilation airflow and ventilation ducts that meet the duct design requirements given in Table 11-25 (Table 160.2-H). This option is limited to ventilation systems with a total duct length less than or equal to 25 ft (8m), with no more than three elbows, and has exterior termination fitting with a hydraulic diameter greater than

or equal to the minimum duct diameter and not less than the hydraulic diameter of the fan outlet.

When using the duct sizing table or manufacturer's design criteria for compliance, the certified airflow rating of the fan must be based on tested performance at the 0.25 inches water column (w.c.) static pressure. The airflow rating of a fan is available from the HVI Certified Products Directory at the HVI website (www.hvi.org/hvi-certified-products-directory).

If the manufacturer's duct system design specifications are used for compliance, the enforcement agency may require that the manufacturer's published system design documentation be provided for use for inspection of the installation(s).

The duct design criteria provided in Table 11-25 identifies the minimum exhaust duct diameter based on airflow. The higher the airflow, the larger the required diameter. Smooth rigid duct can be used to reduce pressure losses for longer duct runs. Interpolation and extrapolation of Table 11-25 are not allowed. To use the table for kitchen exhaust, first determine the required airflow based on unit floor area and range type (gas or electric) using Table 11-22 (from Table 160.2-G in the Standards). Then select the column that lists an airflow equal to or greater than the required airflow and use the duct size listed for rigid duct. If the duct is rectangular, calculate the equivalent diameter using footnote a.

Table 11-25: Prescriptive Ventilation System Duct Sizing (from Table 160.2-H in the Energy Code)

Fan Airflow Rating, cfm at minimum static pressure[f] 0.25 in. water (L/s at minimum 62.5 Pa)	≤50 (25)	≤80 (40)	≤100 (50)	≤125 (60)	≤150 (70)	≤175 (85)	≤200 (95)	≤250 (120)	≤350 (165)	≤400 (190)	≤450 (210)	≤700 (330)	≤800 (380)
Minimum Duct Diameter, in. (mm) [a,b] For Rigid duct	4 [e] (100)	5 (125)	5 (125)	6 (150)	6 (150)	7 (180)	7 (180)	8 (205)	9 (230)	10 (255)	10 (255)	12 (305)	12 [d] (305)
Minimum Duct Diameter, in. (mm) [a,b] For Flex duct [c]	4 (100)	5 (125)	6 (150)	6 (150)	7 (150)	7 (180)	8 (205)	8 (205)	9 (230)	10 (255)	NP	NP	NP

Source: California Energy Commission

Relevant footnotes to table:

a. For noncircular ducts, calculate the diameter as four times the cross-sectional area divided by the perimeter.

f. When a vented range hood utilizes a capture efficiency rating to demonstrate compliance with 160.2(b)2Avic2, a static pressure greater than or equal to 0.25 in. of water at the rating point must not be required, and the airflow listed in the approved directory corresponding to the compliant capture efficiency rating point must be applied to Table 160.2-G for determining compliance.

Example 11-21: Duct Sizing

Question

I need to provide 40 CFM of continuous ventilation, which I plan to do using an exhaust fan. I plan to connect the fan to a roof vent termination using flex duct. The duct will be about 8 ft. long with no real elbows but some slight bends in the duct. What size duct do I need to use?

Answer

From Table 11-25, using the ≤50 CFM column, the size of the flex duct must be 4 inches.

Example 11-22

Question

For the situation in Example 11-21, again providing 40 CFM, what size duct would I need if rigid metal duct were used?

Answer

Using the ≤50 CFM column of Table 11-25, the diameter of rigid duct must also be 4 inches.

Example 11-23

Question

I am installing a gas range in a 1,200 sq. ft dwelling unit, so will need a 250 CFM range hood. What size duct do I need to use?

Answer

Looking at Table 11-25, in the ≤250 CFM column, an 8" duct will be needed. However, this table can only be used if the maximum duct length is 25 ft. and there are fewer than four elbows. As required by §504.3 of the California Mechanical Code, the duct must be rigid metal. Another alternative would be to install a hood with a certified airflow of 250 CFM or greater and install a duct that is the same size or larger as the duct connection to the hood and verify the airflow by testing. If an electric range is installed the airflow (from Table 160.2-G in the Standards) can be reduced to only 110 CFM, which would require a 6" duct.

Example 11-24: Ducting Kitchen Exhaust to the Outdoors

Question

How do I know what kind and what size of duct I need to use for a 900 sq. ft unit with an electric range? I've been using recirculating hoods my entire career, now I need to vent to the outdoors. How do I do it?

Answer

A kitchen range hood or downdraft duct must be a smooth metal duct. If capture efficiency is used for compliance, then airflow must be measured and verified to be equal to or greater than the airflow that corresponds to the listed capture efficiency or the airflow required by Table 160.2-G (Table 1 in this document). The listed airflow is based on whatever duct size is used for the capture efficiency tests, typically the same size as the duct connection to the range hood.

If airflow, instead of capture efficiency, is used for compliance, then the duct size can also be the same size as the connection to the range hood. If the connection to the hood is rectangular (for example 3.25" x 10") and is adapted to round duct, it would be wise to install a 7 inch or larger diameter round duct to achieve compliance with airflow requirements.

An alternative approach that only requires visual inspection can be used if the total duct length is 25 ft or shorter, there are less than four elbows, and the termination fitting is properly sized. In this case the duct size can be selected using Table 160.2-H (ASHRAE Standard 62.2 Table 5-3 or Table 11-24

in this document). The terminal device must have a hydraulic diameter greater than or equal to that of the range hood connection. To calculate the hydraulic diameter, multiply the cross-sectional area of the fan outlet by four and divide by the perimeter.

In your case, from Table 11-22 above you will need a range hood with a capture efficiency of 55% or an airflow of 130 CFM or greater. If you want to comply using visual inspection and can keep the duct under 25 ft. with less than four elbows, then from Table 11-23 you will need a 6-inch duct. If the duct connection to the hood is 4.25" x 10", then the termination fitting must have a hydraulic diameter of at least:

D_h = (4 x 3.25 x 10) / (2 x 3.24 + 2 x 10) = 4.9 square inches

11.4.4.4 Exhaust Ducts

From ASHRAE Standard 62.2, Section 7.3, Exhaust Ducts.

7.3.1 Multiple Exhaust Fans Using One Duct. Exhaust fans in separate dwelling units must not share a common exhaust duct. If more than one of the exhaust fans in a single dwelling unit shares a common exhaust duct, each fan must be equipped with a backdraft damper to prevent the recirculation of exhaust air from one room to another through the exhaust ducting system.

7.3.2 Single Exhaust Fan Ducted to Multiple Inlets. Where exhaust inlets are commonly ducted across multiple dwelling units, one or more exhaust fans located downstream of the exhaust inlets must be designed and intended to run continuously, or a system of one or more backdraft dampers must be installed to isolate each dwelling unit from the common duct when the fan is not running.

The Energy Code contains restrictions on situations where multiple exhausts are connected through a combined duct system. These restrictions are intended to prevent air from moving between spaces through the exhaust ducts.

The first restriction is that if more than one exhaust fan in the same dwelling unit shares a common duct, then each fan must be equipped with a backdraft damper, so air exhausted by one fan is not allowed to go into another space.

The other restriction applies to remote fans serving more than one dwelling unit. Sometimes a single remote fan or HRV/ERV will exhaust air from several dwelling units in a multifamily building. The Energy Code require that either the shared exhaust fan operate continuously, or each unit be equipped with a backdraft damper so that air cannot flow from unit to unit when the fan is off. Note these requirements are also in the California Mechanical Code §504.1.1.

Additionally, §160.2(b)2Ci requires central ventilation system ducts serving multiple dwelling, providing continuous airflows, or part of a balanced ventilation system to be balanced and sealed according to the California Mechanical Code §603.10 and tested in accordance with procedures in Reference Appendix NA7.18.3.

11.4.4.5 Supply Ducts

From ASHRAE Standard 62.2, Section 7.4, Supply Ducts.

Where supply outlets are commonly ducted across multiple dwelling units, one or more supply fans located upstream of all the supply outlets must be designed and intended to run continuously, or a system of one or more backdraft dampers must be installed to isolate each dwelling unit from the common duct when the fan is not running.

Supply outlets to more than one dwelling unit may be served by a single fan upstream of all the supply outlets if the fan is designed to run continuously or if each supply outlet is equipped with a backdraft damper to prevent cross-contamination when the fan is not running.

11.4.5 Other Mandatory Requirements (Section 6 of ASHRAE Standard 62.2 and California Mechanical Code)

All dwelling units must meet the requirements of ASHRAE Standard 62.2, Ventilation and Acceptable Indoor Air Quality in Residential Buildings subject to §160.2(b)2A ventilation requirements. These additional requirements are described below.

The following sections of ASHRAE Standard 62.2 are not required for compliance: Section 4.1.1, Section 4.1.2, Section 4.1.4, Section 4.3, Section 4.6, Section 5, Section 6.1.1, Section 6.5.2, and Normative Appendix A.

11.4.5.1 Instructions and Labeling

From ASHRAE Standard 62.2*, Section 6.2, Instructions and Labeling.*

Information on the ventilation design and/or ventilation systems installed, instructions on their proper operation to meet the requirements of this standard, and instructions detailing any required maintenance (similar to that provided for HVAC systems) must be provided to the owner and the occupant of the dwelling unit. Controls must be labeled as to their function (unless that function is obvious, such as toilet exhaust fan switches).

From Standards §160.2(b)2Aix:

Compliance with ASHRAE Standard 62.2 Section 4.4 (Control and Operation) must require manual ON-OFF control switches associated with dwelling unit ventilation systems to have a label clearly displaying the following text, or equivalent text: "This switch controls the indoor air quality ventilation for the home. Leave switch in the "on" position at all times unless the outdoor air quality is very poor."

Building on the requirements for labeling in ASHRAE Standard 62.2, the Energy Code Section §10-103(b)4 requires the builder to leave in the building for the building owner at occupancy:

- A description of the quantities of outdoor air that the whole-dwelling unit ventilation system(s) are designed to provide and instructions for proper operation and maintenance of the ventilation system.
- Instructions for proper operation and maintenance of local exhaust systems, including instructions for conditions for any occupant-controlled systems such as kitchen range hoods and bathroom exhaust fans that should be used.

For systems in buildings or dwelling unit spaces that are not individually owned by the dwelling unit occupants, the building's owner or their representative should provide:

- A copy of the ventilation system information to dwelling occupants at the beginning of their occupancy.

For systems in buildings or dwelling unit spaces that are centrally operated, the builder should provide:

- All applicable ventilation system information to the person(s) responsible for operating and maintaining the feature, material, component, or mechanical ventilation device installed in the building. This information must be in paper or electronic format.

The Energy Code require that ventilation system controls be labeled as to their function. An acceptable option is to affix a label to the electrical panel that provides some basic system operation information.

11.4.5.2 Clothes Dryers

From ASHRAE Standard 62.2, Section 6.3, Clothes Dryers.

Clothes dryers must be exhausted directly to the outdoors. Exception: Condensing dryers plumbed to a drain.

All dryers in dwelling units must be ducted to the outdoors, with the exception of condensing dryers. Devices that allow the exhaust air to be diverted into the indoor space to provide extra heating are not permitted.

In multifamily buildings, multiple dryer exhaust ducts can be connected to a common exhaust only when dampers are provided to prevent recirculation of exhaust air from one dwelling unit to another.

11.4.5.3 Combustion and Solid-Fuel Burning Appliances

From ASHRAE Standard 62.2, Section 6.4, Combustion and Solid-Fuel Burning Appliances

6.4.1 Combustion and solid-fuel burning appliances must be provided with adequate combustion and ventilation air and installed in accordance with manufacturers' installation instructions; NFPA 54/ANSI Z223.1, National Fuel Gas Code5; NFPA 31, Standard for the Installation of Oil-Burning Equipment6; or NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel Burning Appliances,7, or other equivalent code acceptable to the building official.

6.4.2 Where atmospherically vented combustion appliances or solid-fuel burning appliances are located inside the pressure boundary, the total net exhaust flow of the two largest exhaust fans (not including a summer cooling fan intended to be operated only when windows or other air inlets are open) must not exceed 15 CFM per 100 ft2 (75 L/s per 100 m2) of occupiable space when in operation at full capacity. If the designed total net flow exceeds this limit, the net exhaust flow must be reduced by reducing the exhaust flow or providing compensating outdoor air. Gravity or barometric dampers in nonpowered exhaust makeup air systems must not be used to provide compensating outdoor air. Atmospherically vented combustion appliances do not include direct-vent appliances. Combustion appliances that pass safety testing performed according to ANSI/BPI-1200, Standard Practice for Basic Analysis of Buildings, must be deemed as complying with Section 6.4.2.

The Energy Code require that the ventilation system for combustion appliances including furnaces and gas water heaters to be properly installed, as specified by the instructions from the appliance manufacturer and by the California Building Code. Compliance with the venting requirements involves determining the type of vent material to be used, the sizing of the vent system, and vent routing requirements.

The Energy Code require compensating outdoor air (makeup air) when atmospherically vented appliances are installed inside the pressure boundary if the two largest exhaust fans have a combined capacity that exceeds 15 CFM/100 sq. ft of floor area. Use of atmospherically vented appliances in new multifamily buildings is rare or nonexistent, but observation of this ASHRAE requirement will improve combustion even if atmospherically vented appliances are not installed.

The two largest exhaust fans are normally the kitchen range hood and the clothes dryer. In many cases, the range hood airflow/capture efficiency requirements result in the range hood alone exceeding the 15 CFM/100 sq. ft limit. Thus, many units with atmospherically vented appliances will require makeup air fan. Example 4-13 discusses an example of a multifamily unit using an atmospherically vented water heater.

A supply fan can be used to balance the exhaust airflow, but from an equipment, operating cost, maintenance cost, comfort, and safety standpoint, atmospherically-vented appliances are not recommended inside dwelling units, as illustrated in the example below.

Example 11-25: Gas Water Heater

Question

We are designing a multifamily building with unit sizes ranging from 750 sq. ft with one bedroom to 1200 sq. ft with three bedrooms. Half of the floor area will be open space (living areas and kitchen). Ceiling heights are nine ft. The building will have a community laundry, and each unit will have a 36,000 Btuh naturally vented gas water heater in an interior closet off the kitchen and will use continuously operating bathroom fans to meet whole unit ventilation requirements. How many CFM of compensating air must be provided? What are the alternatives to providing compensating fans?

Answer

The California Mechanical Code allows atmospherically vented appliances to use indoor air for combustion if the space has 50 ft^3 of interior volume for every 1000 Btuh of gas input, provided there are no interior doors isolating the space used to provide air to the appliance. Per the Mechanical Code the volume needed is 36,000 / 1000 x 50 = 1800 ft^3 so a 200 sq. ft space with 9 ft. ceilings would be sufficient. The smallest unit has 750 x 50% = 375 sq. ft of open area and will meet this requirement.

Per Table 160.2-G, the 750 sq. ft unit will need a range hood with a capacity of 280 CFM and the 1200 sq. ft unit will need 250 CFM. To maintain indoor air quality, the 750 sq. ft unit will need 38 CFM of mechanical ventilation and the 1200 sq. ft unit will need 66 CFM (from Equation 160.2-B).

So, the maximum exhaust rate will be 280 + 38 = 318 CFM for the small unit and 250 + 66 = 316 CFM for the large unit. The Energy Code limit for exhaust ventilation without compensation is 15 / 100 x 750 = 113 CFM for the small unit and 15 / 100 x 1200 = 180 CFM for the large unit. That leaves a deficit of 318 – 113 = 305 CFM for the small unit and 316 – 180 = 136 CFM for the large unit, which are the minimum sizes of the compensating (makeup air) fans required.

Although installing atmospherically vented water heaters inside the units can be made to be code compliant, it is highly undesirable due to the cost of the compensating fans, which must be controlled in parallel with the kitchen range hoods, the energy and comfort impact of delivering high volumes of unconditioned air to the units, and filter maintenance costs. Direct vented tankless water heaters or heat pump water heaters would be a far better alternative.

11.4.5.4 Ventilation Opening Area

From ASHRAE Standard 62.2, Section 6.6 Ventilation Opening Area.

Spaces must have ventilation openings as listed in the following subsections. Such openings must meet the requirements of Section 6.8.

Exception: Attached dwelling units and spaces that meet the local ventilation requirements set for bathrooms in Section 5.

6.6.1 Habitable Spaces. Each habitable space must be provided with ventilation openings with an openable area not less than 4% of the floor area or less than 5 ft2 (0.5 m2).

6.6.2 Toilets and Utility Rooms. Toilets and utility rooms must be provided with ventilation openings with an openable area not less than 4% of the room floor area or less than 1.5 ft2 (0.15 m2).

Exceptions:

1. Utility rooms with a dryer exhaust duct.

2. Toilet compartments in bathrooms.

While this section of ASHRAE Standard 62.2 requires that single-family homes have ventilation openings (typically operable windows) for all habitable spaces, multifamily dwelling units are exempt from this requirement. There are no requirements for ventilation openings areas for multifamily units in the Energy Code. It is best practice to design multifamily units to meet this design practice, if possible, to provide adequate ventilation during circumstances where high levels of contaminants are released into the space. Operable windows are the most likely means of providing additional ventilation. Additional ventilation can also be provided by operable skylights; through-the-wall vents; or similar devices that are readily accessible to the occupant. An operable skylight should have some means of being operated while standing on the floor: a push rod, a long crank handle, or an electric motor.

Ventilation openings should have openable area equal to at least 4% of the space floor area (but not less than five sq. ft).

Example 11-26: Ventilation Openings

Question

I have a dwelling unit with a 14 ft. by 12 ft. bedroom. What size window should I install?

Answer

Multifamily dwelling units are exempted from requiring windows. However, as a best practice, window sizes should follow the single-family design requirements. The openable area of the window, not the window unit, should be 4% of the floor area, or 14 ft x 12 ft x 0.04 = 6.7 sq. ft or greater. The recommendation for this example can be met using two double-hung windows, each with a fully opened area of 3.35 sq. ft. Any combination of windows whose opened areas add up to at least 6.7 sq. ft will meet the recommendation.

11.4.5.5 Air Inlets

From ASHRAE 62.2, Section 6.8, Air Inlets.

Air inlets that are part of the ventilation design must be located a minimum of 10 ft (3 m) from known sources of contamination such as a stack, vent, exhaust hood, or vehicle exhaust. The intake must be placed so that entering air is not obstructed by snow, plantings, or other material. Forced air inlets must be provided with rodent/insect screens (mesh not larger than 1/2 in. [13 mm]).

Exceptions:

1. Ventilation openings in the wall may be as close as a stretched-string distance of 3 ft (1 m) from sources of contamination exiting through the roof or dryer exhausts.

2. No minimum separation distance must be required between windows and local exhaust outlets in kitchens and bathrooms.

3. Vent terminations covered by and meeting the requirements of the National Fuel Gas Code (NFPA 54/ANSI Z223.1)7 or equivalent.

4. Where a combined exhaust/intake termination is used to separate intake air from exhaust air originating in a living space other than kitchens, no minimum separation distance between these two openings is required. For these combined terminations, the exhaust air concentration within the intake airflow must not exceed 10%, as established by the manufacturer.

6.8.1 Ventilation Openings.

Operable windows, skylights, through-the-wall inlets, window air inlets, or similar devices must be readily accessible to occupants. Where openings are covered with louvers or otherwise obstructed, openable area must be based on the free, unobstructed area through the opening.

When the ventilation system is designed with outdoor air inlets, the inlets must be located away from locations that can be expected to be sources of contamination. The minimum separation is 10 ft. Inlets include not only inlets to ducts, but windows that are needed to achieve the minimal opening area.

For residential buildings, typical sources of outdoor air contaminants include:

1. Vents from combustion appliances
2. Fireplace chimneys.

3. Exhaust fan outlets.
4. Barbeque grills.
5. Driveways or any location where vehicles may be idling.
6. Any other locations where outdoor air contaminants are generated.

The Energy Code also requires that air intakes be placed so that they will not become obstructed by snow, plants, or other material. Forced air inlets must also be equipped with insect/rodent screens with mesh is no larger than 1/2 inch.

11.4.6 Common Use Area Ventilation Requirements

This section provides an overview of the Energy Code requirements for ventilation and ventilation systems serving common use areas of the building, such as community rooms, corridors, fitness areas, common laundry rooms, and parking garages. This section also discusses whether the Energy Code or California Mechanical Code (CMC, or Title 24 Part 4) takes precedent, for areas where both standards provide requirements.

Since there are similar requirements for ventilation systems serving common use area and systems serving nonresidential occupancies, more detailed discussion of the applicable requirements can be found in Chapter 4.3 for the applicable requirements.

Requirements for systems serving nonresidential occupancies in mixed occupancy buildings are in Section 120, 130, 140 and 141 of the Energy Code.

11.4.6.1 Common Use Area Ventilation Prescriptive Requirements

Applicable Prescriptive requirements for common use area ventilation system include:

- Common Use Area Space Conditioning Systems, which includes requirements for space conditioning as well as ventilation - §170.2(c)4

11.4.6.2 Performance Approach

Applicable Performance approach requirements for common use area ventilation systems include:

11.4.6.3 Common Use Area Ventilation Performance Approach

§170.1 specifies the performance approach for common use area ventilation.

11.4.7 Additions and Alterations

§180.1(a)2, §180.1(b)3, and §180.2(b)5

This section describes dwelling unit and common use area ventilation requirements for additions and alterations, including the scopes that trigger these requirements.

For both additions and alterations, when HERS field verification is required, buildings with up to three habitable stories should use the applicable procedures in the Residential Appendices. All HERS forms must be registered online with a HERS Provider. (See Section 2.5 and Appendix A.) Buildings with four or more habitable stories should use the applicable procedures in Nonresidential Appendices NA1 and NA2.

11.4.7.1 Additions

11.4.7.2 Dwelling Unit

For additions to existing buildings, local mechanical exhaust should comply with all applicable requirements specified in §160.2(b)2Avi (Local Mechanical Exhaust) and §160.2(b)2B (Dwelling Unit HERS Field Verification and Diagnostic Testing).

For whole-dwelling unit mechanical ventilation, the following requirements apply:

- For additions to an existing dwelling unit that increase conditioned floor area by more than 1,000 sq. ft, the mechanical ventilation airflow must be in accordance with §160.2(b)2Aiv (Whole-Dwelling unit Mechanical Ventilation) or §160.2(b)2Av (Central Ventilation System Airflow Rate Tolerance), as applicable. The mechanical ventilation airflow rate should be based on the conditioned floor area of the entire dwelling unit including the existing and additional conditioned floor area.
- For new dwelling units that are additions to an existing building, mechanical ventilation must meet §160.2(b)2Aiv or §160.2(b)2Av, as applicable. The mechanical ventilation airflow rate should be based on the conditioned floor area of the new dwelling unit.
- Dwelling units do not have to meet the whole-dwelling unit ventilation airflow requirements of §160.2(b)2Aiv or §160.2(b)2Av if the addition increases the existing dwelling unit conditioned floor area by less than or equal to 1000 sq. ft.

11.4.7.3 Common Use Area

Additions to the common use area should follow the nonresidential building requirements. Any newly installed space conditioning system must meet the ventilation requirements in §120.1 (Requirements for Ventilation and Indoor Air Quality) for both the prescriptive and performance approaches.

11.4.7.4 Alterations

11.4.7.5 Dwelling Unit

If the ventilation system is entirely new or a complete replacement, the ventilation system should comply with all applicable requirements in §160.2(b)2 (Ventilation and Indoor Air Quality Requirements for Attached Dwelling Units). An entirely new ventilation system includes a new ventilation fan component and an entirely new duct system, where an entirely new duct system should be at least 75% new duct material. Up to 25% of the duct system may be made up of reused parts of the existing duct system.

For altered ventilation system components or newly installed ventilation equipment serving the alteration, requirements are dependent on the component and requirements under the previous building permit.

For whole-dwelling unit mechanical ventilation:

- For an altered or replaced whole-dwelling ventilation system, if a previous building permit required compliance with whole-dwelling unit airflow requirements in §160.2(b)2, the whole-dwelling unit mechanical ventilation airflow must meet or exceed requirements specified in §160.2(b)2Aiv or §160.2(b)2Av. Otherwise, compliance is not required.
- Whole-dwelling unit replacement ventilation fans should be rated for airflow and sound in accordance with requirements in ASHRAE Standard 62.2 Section 7.1 and 7.2. If a specified airflow is required for compliance, the fan should be rated at an airflow no less than airflow rate required for compliance.
- For an altered or replaced air filtration device, if a previous building permit required air filtration requirements in §160.2(b)1, the altered or replacement filtration device must comply with air filtration requirements in §160.2(b)1. Otherwise, compliance is not required.

For local mechanical exhaust systems:

- Altered bathroom local mechanical exhaust systems should comply with applicable requirements specified in §160.2(b)2Avi.
- For a kitchen local ventilation fan that is altered or replaced, if a previous building permit required compliance with local exhaust requirements in §160.2(b)2Avi, the applicable airflow and capture efficiency must meet or exceed requirements in §160.2(b)2Avi. If a previous building permit required installation of a vented kitchen range hood or other kitchen exhaust fan, the replacement fan must have an airflow that meets or exceed requirements of the previous building permit, or 100 CFM, whichever is greater. Otherwise, compliance is not required.
- New or replacement local mechanical exhaust fans should be rated for airflow and sound in accordance with requirements of ASHRAE Standard 62.2 Section 7.1 and §160.2(b)2Avif. If a specified exhaust airflow is required for compliance, the fan should be rated at not less than the required airflow.

For alterations to space conditioning systems in existing buildings that have all or portions of the forced air ducts, plenums or air-handling units in the garage, there are leakage requirements discussed in "Duct System Sealing and Leakage Testing" in Section 11.6.4 of the Building Space Conditioning Systems section. Note that for the central ventilation system duct sealing test, the sampling group consists of no more than three central ventilation duct systems.

11.4.7.6 Common Use Area

Alterations to the common use area should follow the nonresidential building requirements. Any altered components of space conditioning systems or newly installed space conditioning systems must meet the ventilation requirements in §120.1 (Requirements for Ventilation and Indoor Air Quality) for both the prescriptive and performance approaches.

11.4.8 Compliance and Enforcement

Compliance with the Standard requirements must be verified by the enforcement agency, except for the requirements listed in Table 11-10Table , which must be verified by a HERS Rater or ATT. As a summary, HERS raters:

- Conduct dwelling unit air leakage testing (compartmentalization / blower door test).
- Verify ERV/HRV listing in the HVI directory, nominal airflow, and (in dwelling units in buildings up to three habitable stories) sensible recovery efficiency and fan efficacy.
- Verify kitchen exhaust range hood listing in the HVI or AHAM directory, compliance based on nominal airflow or capture efficiency, and sound rating.

ATTs:

- Verify ERV/HRV sensible recovery effectiveness and fan power allowance in dwelling units in buildings four or more habitable stories.
- Conduct functional bypass testing for central ERVs /HRVs.
- Conduct an air leakage testing measurement in central ventilation ducts.

11.4.8.1 Design-Phase Documentation Requirements

This subsection describes design-phase documents for multifamily buildings.

The performance approach allows compliance credit for special additional features to be quantified. The certificate of compliance lists features for which special compliance credit was taken using the performance approach. They require additional visual verification by the enforcement agency to ensure proper installation. Some require field verification and diagnostic testing by a HERS Rater or ATT. These will be listed in a separate section.

The mechanical ventilation rate (Qfan) must be manually calculated using the applicable equations in §160.2(b)2Aiv. The value for Qfan is required to be reported on the certificate of compliance. The performance certificate of compliance will report the:

- Minimum mechanical ventilation airflow rate (calculated value) that must be delivered by the system.
- Type of ventilation system (exhaust, supply, balanced, CFI).
- Fan efficacy (W/CFM) for the selected system.
- Recovery efficiency (%) (applicable to HRV/ERV system types only)
- For CFI systems--HERS verification of air handler fan efficacy is required.

The installed dwelling unit ventilation system must conform to the performance requirements on the certificate of compliance.

The enforcement agency may require additional information/documentation describing the ventilation systems be submitted along with the certificate of compliance at plan check.

11.4.8.2 Construction-Phase Documentation

This subsection describes construction-phase documents for multifamily buildings up to three stories. For multifamily buildings with four or more stories, the equivalent processes must be followed using nonresidential forms.

During construction, the general contractor or specialty subcontractors must complete all applicable certificate of installation documents for the building design special features specified on the certificate of compliance. The builder/installer must complete certificates of installation for the dwelling.

Like the certificate of compliance, registration of the certificate of installation is required, except for multifamily buildings with four stories and more. For all other buildings, the licensed contractor responsible for the installation must submit the certificate of installation information that applies to the installation to a HERS Provider Data registry using procedures described in §10-103 and Section RA2 of the Reference Residential Appendix. Certificate of installation documents corresponding to the list of special features requiring HERS Rater or ATT verification are required. For buildings with four or more stories, the licensed contractor responsible for the installation must complete and submit the certificate of installation to the building department or jurisdiction having authority.

E. Certificate of Installation

The following information must be provided on the certificate of installation to identify each ventilation system/fan in the dwelling that will require HERS verification.

For dwelling unit ventilation systems:

- Ventilation system name or identification
- Ventilation system location
- Ventilation system control type (i.e., continuous, variable)

- Ventilation system type (i.e., exhaust, supply, balanced).
- Ventilation system target airflow rate (may be less than Q_{fan} if using multiple systems/fans to comply)
- Ventilation system manufacturer name
- Ventilation system model number
- Control system manufacturer (if applicable)
- Control system model number (if applicable)
- Energy Commission certification number for variable system/control (if applicable)
- ERV or HRV manufacturer name (if applicable)
- ERV or HRV model number (if applicable)
- ERV or HRV location (if applicable)
- ERV or HRV type (i.e., unitary or central, if applicable)
- Presence of bypass recovery bypass or free cooling function (if applicable)
- Duct system name or identification
- Dust system description of area served
- Supply duct location
- Return duct location
- Sealing materials used for duct system (if applicable)

For kitchen exhaust ventilation systems:

- Kitchen exhaust control type (i.e., demand-controlled, continuous)
- Kitchen exhaust system type (i.e., range hood, over-the-range microwave, downdraft, local exhaust, other)
- Kitchen exhaust system required airflow rate or capture efficiency for demand-controlled or downdraft, and minimum kitchen air exchange rate (ACH50) for continuous systems
- Kitchen exhaust system manufacturer name
- Kitchen exhaust system model number

The following additional information must be provided on the certificate of installation to document compliance with §160.2 and 170.2(c)3B. Refer also to the procedures in RA 3.7.4 for dwelling units in buildings up to three habitable stories, and sections including NA 1.1 for dwelling units in buildings four or more habitable stories.

For dwelling unit ventilation systems:

- Measured airflow rate of the installed dwelling unit ventilation system. For balanced systems, exhaust and supply airflows must be measured and recorded.
- Installed ERV or HRVs' nominal sensible recovery efficiency and fan efficacy, if applicable.
- Installed exhaust or supply dwelling unit ventilation efficacy, if applicable.
- Installed dwelling unit ventilation system fan sone rating for fans that are not remotely mounted.
- Confirmation installed ERV or HRV has a sensible recovery efficiency and fan efficacy greater than those specified in standards.
- If a central ERV or HRV is installed, confirmation that the installed ERV or HRV includes a bypass or free cooling function.

For kitchen exhaust ventilation systems:

- Confirmation the installed system is rated by HVI or AHAM to meet the required airflow or capture efficiency and sound requirements
- The rated airflow value or rated capture efficiency listed in the HVI or AHAM directory
- The sound rating listed in the HVI or AHAM directory
- Confirmation the value for the rated airflow or capture efficiency given in the HVI directory is greater than or equal to those specified in the standards, and the value for the sone rating given in the directory is less than or equal to the sone rating requirements in specified standards.

For central ventilation systems that provide dwelling unit ventilation or operates continuously:

- Confirmation an ATT has performed a duct leakage field verification
- Documentation of duct leakage field verification showing flow rate measurement that meets requirements of specified standards

For all ventilation systems:

- Confirmation that the other applicable requirements given in Sections 6 and 7 of ASHRAE Standard 62.2 as amended in 160.2 have been met (see Sections 11.4.4 and 11.4.5)

11.4.8.3 Field Verification and Diagnostic Testing

This subsection describes field verification and diagnostic testing for multifamily buildings.

Table 11-10 lists special features requiring HERS Rater or ATT field verification or diagnostic testing for multifamily buildings. For buildings for which the certificate of compliance requires HERS or ATT field verification for compliance with the Energy Code, a HERS Rater or ATT must visit the site to perform field verification and diagnostic testing to complete the applicable heating and cooling system certificates of field verification and diagnostic testing. Certificate of verification documents corresponding to the list of special features requiring HERS Rater or ATT verification are required.

Field verification for nonmandatory features is necessary only when performance credit is taken for the feature. Some field verifications are for mandatory requirements and will occur in all multifamily buildings unless they are exempt from the requirement.

Like the certificate of compliance and certificate of installation, registration of the certificate of verification is required. The HERS Rater must submit the field verification and diagnostic testing information to the HERS Provider Data Registry as described in RA2 of the Residential Appendix and NA2 of the Nonresidential Appendix. For features requiring ATT verification, the ATT must follow the procedures described in NA1.9.

For multifamily buildings up to three habitable stories: verification, testing, and sampling procedures should follow the Residential Appendix requirements for these features, which are primarily located in RA 2.6 (sampling) and RA3.7 (Field Verification and Diagnostic Testing of Mechanical Ventilation Systems). For multifamily buildings four or more habitable stories: verification, testing, and sampling procedures should follow the Nonresidential Appendix requirements for these features, which are primarily found in sections NA1.6 (sampling), NA 2.2 (Field Verification and Diagnostic Testing of Mechanical Ventilation Systems), and NA 7.18 (Multifamily Building Acceptance Tests). The central ventilation duct sealing test has unique sampling requirements, in that the ATT's sampling group may consist of no more than three central ventilation duct systems in the building.

11.5 Building Space Conditioning System Requirements

This section addresses the requirements for space conditioning systems in multifamily buildings. Requirements related to ventilation and indoor air quality are discussed in Chapter 11.4.

Requirements for a space conditioning system that serves one or more dwelling units are described in Chapters 11.6.3 and 11.6.4. Requirements for a space conditioning system that serves common use areas of the building—including community rooms, corridors, fitness areas, common laundry rooms, and parking garages—are described in Chapter 11.6.5. Space conditioning systems that serve both dwelling units and common use areas must meet both sets of requirements.

Systems serving nonresidential occupancies in a mixed occupancy building must comply with nonresidential requirements in §120.0 through §141.1. See Chapter 4 for information on those systems.

Chapter 11.6.7 covers the heating and cooling requirements for additions to existing dwellings and for alterations to existing heating and cooling systems.

Table 11-26: Overview of Space Conditioning System Requirements in the Energy Code and Compliance Manual Organization

Space Conditioning System Application	Mandatory Requirements	Prescriptive Requirements	Performance Approach Requirements	Manual Chapter
Dwelling Units	§110.2, §110.5, §160.2(b)1, §160.3(a)(b)(d)	§170.2(c)3	§170.1	11.6.3 11.6.4 11.6.6
Common Use Areas	§110.2, §110.5, §110.9, §110.12, §160.2(c)1, §160.3(a)(c)(d)	§170.2(c)1,2,4	§170.1	11.6.5
Additions and Alterations	§110.2, §110.5, §110.9, §160.2(c), §160.3, §180.1	§180.1(a)	§180.1(b)	11.6.7

Source: California Energy Commission

11.5.1 What's New for the 2022 Energy Code

The following is an overview of the new HVAC requirements for the *2022 Building Energy Efficiency Standards* (Energy Code).

- The mandatory testing requirements that applied to multifamily buildings up to three habitable stories under the 2019 Energy Code (duct leakage, airflow rate, and fan efficacy) now apply to all multifamily buildings with HVAC systems serving individual dwelling units with some exceptions. The HERS Rater field verification and HERS Provider data registry requirements of Reference Residential Appendix RA2 and RA3 are not required for multifamily dwelling units in buildings with four or more habitable stories. In these cases, the installer must certify on the Certificate of Installation that diagnostic testing was performed in accordance with the applicable procedures.
- For dwelling units in multifamily buildings with up to three habitable stories, the prescriptive approach requires the space conditioning system to be a heat pump in Climate Zones 1-15. For Climate Zone 16, the space conditioning system must be an air conditioner with a gas-fired furnace. In addition, in Climate Zones 4-10, if the ventilation system is a balanced system without heat or energy recovery, the fan efficacy must be 0.4 W/CFM or less.

- For dwelling units in multifamily buildings with four or more habitable stories prescriptive approach requires the space conditioning system to be a heat pump in Climate Zones 2-15. For Climate Zones 1 and 16, the space conditioning system should be a dual-fuel heat pump.
- The prescriptive refrigerant charge testing requirements that applied to multifamily buildings up to three habitable stories the 2019 Energy Code now apply to all multifamily buildings with HVAC systems serving individual dwelling units. The HERS Rater field verification and HERS Provider data registry requirements of Reference Residential Appendix RA2 and RA3 are not required for multifamily dwelling units in buildings with four or more habitable stories. In these cases, the installer must certify on the certificate of installation that diagnostic testing was performed in accordance with the applicable procedures.
- Ducts in conditioned space can be uninsulated if specific conditions are met, as explained in Chapter 11.6.4
- New requirements for space conditioning system that serve common use areas of the building are described in Chapter 4.1.
- Filter racks or grilles must use a gasket, sealing or other means to prevent air from bypassing the filter
- Variable Capacity Heat Pump Compliance Option that was approved in November 2019 is incorporated into the Energy Code

For alterations and additions, the following changes are included:

- For altered duct systems the prescriptive duct insulation R-Value is R-8 in Climate Zones 1-2, 4, and 8 through 16.
- The 40-foot trigger for prescriptive duct sealing and insulation has been reduced to 25 ft. for altered systems. The minimum length requirement for additions has been eliminated, and duct sealing is required whenever an existing duct system is extended to serve an addition.

A new prescriptive requirement for insulation and sealing in vented attics was added, which is triggered by the installation of an entirely new or complete replacement duct system is in a vented attic. Requirements apply in all climate zones, except 5 and 7, and various exceptions are allowed. See Chapter 11.6.7.2 of the compliance manual for additional details.

11.5.2 California Appliance Standards and Equipment Certification

§110.0 and §110.1

Most heating and cooling equipment installed in California multifamily buildings is regulated by the National Appliance Efficiency Conservation Act (NAECA) and/or the California *Appliance Efficiency Regulations (Title 20)*. Both the federal and state appliance standards apply to the manufacturing and sale of new equipment, whether for installation or replacement in newly constructed buildings, additions, or alterations. The *Appliance Efficiency Regulations* are enforced at the point of sale (except central split-system air conditioners and central single package air conditioners, see Table 11-27), while the Energy Code explained in this compliance manual is enforced by local enforcement agencies.

The equipment listed below is covered by the *Appliance Efficiency Regulations*. The manufacturer must certify that the equipment complies with the current *Appliance Efficiency Regulations* at the time of manufacture. The energy efficiency of other equipment, usually larger equipment, is regulated by the Energy Code §110.2(a).

Appliances covered by the *Appliance Efficiency Regulations* include:

- Room air-conditioners
- Room air-conditioning heat pumps
- Central air conditioners with a cooling capacity of less than 135,000 British thermal units per hour (Btu/hr.)
- Central air conditioning heat pumps
- Gas-fired central furnaces
- Gas-fired boilers
- Gas-fired furnaces
- Gas-fired floor furnaces
- Gas-fired room heaters
- Gas-fired duct furnaces
- Gas-fired unit heaters

The *Appliance Efficiency Regulations* do not require certification for:

- Electric resistance space heaters.
- Oil-fired wall furnaces, floor furnaces, and room heaters. (Some are voluntarily listed with certified gas-fired furnaces.)

Equipment that does not meet the federal appliance efficiency standards may not be sold in California. Any equipment covered by the *Appliance Efficiency Regulations* and sold in California must have the date of manufacture permanently displayed in an accessible place on that equipment. This date is frequently included as part of the serial number.

Generally, equipment manufactured before the effective date of a new standard may be sold and installed in California indefinitely as long as the performance approach demonstrates energy compliance of the building using the lower efficiency of the relevant appliances. An exception is central split-system air conditioners and central single package air conditioners installed in California. The U.S. Department of Energy (DOE) requires compliance with the minimum efficiencies specified in Table 11-27 at the time of installation.

The compliance and enforcement processes should ensure that all installed HVAC equipment regulated by the *Appliance Efficiency Regulations* is certified by the California Energy Commission.

11.5.3 Dwelling Unit Space Conditioning Equipment Requirements

Dwelling unit space conditioning systems must meet the following mandatory Energy Code requirements:

- Space Conditioning Equipment Certification and Equipment Efficiency: §110.1, §110.2
- Restrictions on Pilot Lights for Natural Gas Appliances and Equipment: §110.5
- Space Conditioning System Controls: §160.3(a) 1. Dwelling Unit Thermostats
- Dwelling Unit Space Conditioning and Air Distribution Systems: §160.3 (b)
- Fluid Distribution Systems – Pipe Insulation: §160.3(b)6, §160.3 (c)1.

Prescriptive requirements include:

Prescriptive requirements for Space Conditioning Systems are in §170.2(c)3.

The requirements for the performance approach are in §170.1.

11.5.3.1 Mandatory Requirements

This section addresses the mandatory requirements for heating and cooling equipment, including furnaces, boilers, heat pumps, air conditioners, and electric resistance equipment, serving multifamily dwelling units. Residential equipment used in common use areas must meet these mandatory requirements. Commercial equipment used in common use areas must meet the mandatory requirements described in Chapter 11.6.5.1.

11.5.3.2 Equipment Efficiency

§110.1 and §110.2(a)

The efficiency of most dwelling unit heating and cooling equipment is regulated by the National Appliance Energy Conservation Act of 1987 (NAECA, the federal appliance standard) and California's *Appliance Efficiency Regulations*. These regulations are not contained in the Energy Code but are published separately. These regulations are referenced in §110.1. The energy efficiency of larger equipment is regulated by §110.2(a). The *Appliance Efficiency Regulations* include definitions for all types of equipment and are regularly updated.

Note: The *Appliance Efficiency Regulations* that are in effect when the building permit is applied for will determine the minimum efficiency of the appliances identified in the compliance documentation.

L. Central, Single-Phase Air Conditioners and Air Source Heat Pumps

Central, single-phase air conditioners and air source heat pumps commonly installed in multifamily dwelling units have a capacity less than 65,000 Btu/hr.

Air conditioner efficiencies are determined according to federal test procedures. The efficiencies are reported in terms of SEER and EER. The *Appliance Efficiency Regulations* for this equipment require minimum SEER. The SEER of all new central, single-phase air conditioners and air source heat pumps with an output less than 65,000 Btu/h must be certified to the Energy Commission to have values no less than the values listed in Table 11-27.

Table 11-27: Minimum Cooling Efficiencies for Central Air Conditioners and Heat Pumps

(Cooling Capacity Less Than 65,000 Btu/h)

(NR = No Requirement) Appliance	Type	SEER	EER
Central Air Conditioners[1]	Split-System <45,000 Btu/h	14	12.2
Central Air Conditioners[1]	Split-System 45,000 Btu/h	14	11.7
Central Air Conditioners[1]	Single-Package	14	11.0
Central Air Source Heat Pumps	Split-System	14	NR
Central Air Source Heat Pumps	Single-Package	14	NR
Space-Constrained Air Conditioner	Split-System	12	NR
Space-Constrained Air Conditioner	Single-Package	12	NR
Space-Constrained Heat Pump	Split-System	12	NR
Space-Constrained Heat Pump	Single-Package	12	NR
Small-Duct, High-Velocity Air Conditioner	All	12	NR
Small-Duct, High-Velocity Heat Pump	All	12	NR

1. *See 10 CFR section 430.32(c) for less stringent federal standards applicable to these units that are manufactured on or after January 1, 2015, and installed in states other than Arizona, California, Nevada, or New Mexico.*

Source: California Appliance Efficiency Regulations, Title 20, Table C-3, and Federal Appliance Standards (NAECA)

M. Heat Pumps and Electric Heating

Efficiency requirements for package terminal air conditioners, package terminal heat pumps, single-package vertical air conditioners, and single-package vertical heat pumps are listed in Table 110.2-E of the Energy Code.

Heat pumps must be certified to have a HSPF or coefficient of performance (COP) equal to or better than those listed in Table 11-28.

There are no minimum appliance efficiency standards for electric-resistance or electric-radiant heating systems.

Table 11-28: Minimum Heating Efficiency for Heat Pumps

Equipment Type	Reference	Configuration/Size	Minimum Heating Efficiency
Single-phase air source heat pumps (NAECA)	Table C-3	< 65,000 Btu/h cooling	Packaged 8.0 HSPF Split 8.2 HSPF
Single-phase air source heat pumps (NAECA)	Table C-3	Space constrained < 65,000 Btu/h cooling capacity	7.4 HSPF
Single-phase air source heat pumps (NAECA)	Table C-3	Small duct, high velocity < 65,000 Btu/h cooling capacity	7.2 HSPF
Three-phase air source heat pumps	Table C-4	< 65,000 Btu/h	Packaged 8.0 HSPF Split 8.2 HSPF
Three-phase air source heat pumps	Table C-4	≥ 65,000 and <135,000	3.3 COP (Equipment manufactured starting January 1, 2018) 3.4 COP (Equipment manufactured starting on January 1, 2023)
Three-phase air source heat pumps	Table C-4	≥ 135,000 and <240,000	Electric resistance heating: 3.2 COP (Equipment manufactured starting January 1, 2018) 3.3 COP (Equipment manufactured starting on January 1, 2023) All other: 3.3 COP (Equipment manufactured starting January 1, 2018) 3.4 COP (Equipment manufactured starting on January 1, 2023)
Three-phase air source heat pumps	Table C-4	≥ 240,000 and <760,000	3.2 COP
Water-source heat pumps	Table C-5	<17,000 Btu/h	4.3 COP
Water-source heat pumps	Table C-5	≥ 17,000 Btu/h, < 135,000 Btu/h	4.3 COP
Single package vertical heat pumps	Table C-6	< 65,000 single-phase	3.3 COP (Equipment manufactured starting on September 23, 2019)
Single package vertical heat pumps	Table C-6	< 65,000 3-Phase	3.3 COP (Equipment manufactured starting on September 23, 2019)

Source: California Appliance Efficiency Regulation Title 20

N. Other Air Conditioners and Heat Pumps

Appliance Efficiency Regulations

The *Appliance Efficiency Regulations* contain minimum efficiency requirements for three-phase models, larger-capacity central air conditioners and heat pumps, and all room air conditioners and room air conditioner heat pumps. The efficiency for these types of equipment must be certified to the Energy Commission by the manufacturer. Table 11-29 and Table 11-30 include efficiency requirements for equipment with a cooling capacity less than 65,000 Btu/hour. Efficiency requirements for larger equipment requirements are covered in Chapter 4.

Table 11-29: Minimum Cooling Efficiency for Three-Phase Models and Central Air Conditioners and Heat Pumps

Equipment Type	Size Category	SEER or EER
Central Air-Conditioners	< 65,000 Split-System*	13.0 SEER
Central Air-Conditioners	< 65,000 Single-Packaged*	13.0 SEER
Central Air-Source Heat Pumps	< 65,000 Split-System*	13.0 SEER
Central Air-Source Heat Pumps	< 65,000 Single-Packaged*	13.0 SEER
Central Water-Source Heat Pumps	< 17,000 Btu/h	11.2 EER
Central Water-Source Heat Pumps	≥ 17,000 Btu/h and < 65,000 Btu/h	12.0 EER
Water-Cooled Air Conditioners	< 17,000 Btu/h	12.1 EER
Water-Cooled Air Conditioners	≥ 17,000 < 65,000 Btu/h	12.1 EER

* Three-phase models only

1 Applies to equipment that has electric resistance heat or no heating.

2 Applies to equipment with all other heating-system types that are integrated into the unitary equipment.

3. Deduct 0.2 from the required EER for units with heating sections other than electric resistance heat.

Source : California Appliance Efficiency Regulations Table C-4, C-5

Table 11-30: Minimum Cooling Efficiency for Noncentral Space-Cooling Equipment

Equipment Type	Size Category (Input)	Minimum Efficiency
Room Air Conditioners, With Louvered Sides	< 6,000 Btu/h	11.0 EER
Room Air Conditioners, With Louvered Sides	≥ 6,000 Btu/h and - 7,999 Btu/h	11.0 EER
Room Air Conditioners, With Louvered Sides	≥ 8,000 Btu/h and - 13,999 Btu/h	10.9 EER
Room Air Conditioners, With Louvered Sides	≥ 14,000 Btu/h and - 19,999 Btu/h	10.7 EER
Room Air Conditioners, With Louvered Sides	≥ 20,000 Btu/h and 27,999 Btu/h	9.4 EER
Room Air Conditioners, With Louvered Sides	≥ 28,000 Btu/h	9.0 EER
Room Air Conditioners, Without Louvered Sides	< 6,000 Btu/h	10.0 EER
Room Air Conditioners, Without Louvered Sides	≥ 6,000 Btu/h and - 7,999 Btu/h	10.0 EER
Room Air Conditioners, Without Louvered Sides	≥ 8,000 Btu/h and - 10,999 Btu/h	9.6 EER
Room Air Conditioners, Without Louvered Sides	≥ 11,000 Btu/h and - 13,999 Btu/h	9.5 EER
Room Air Conditioners,	≥ 14,000 Btu/h and - 19,999 Btu/h	9.3 EER

Equipment Type	Size Category (Input)	Minimum Efficiency
Without Louvered Sides		
Room Air Conditioners, Without Louvered Sides	≥ 20,000 Btu/h	9.4 EER
Room Air Conditioner Heat Pumps With Louvered Sides	< 20,000 Btu/h	9.8 EER
Room Air Conditioner Heat Pumps With Louvered Sides	≥ 20,000 Btu/h	9.3 EER
Room Air Conditioner Heat Pumps Without Louvered Sides	< 14,000 Btu/h	9.3 EER
Room Air Conditioner Heat Pumps Without Louvered Sides	≥ 14,000 Btu/h	8.7 EER
Casement-Only Room Air Conditioner	All Capacities	9.5 EER
Casement-Slider Room Air Conditioner	All Capacities	10.4 EER

Cap. = Cooling Capacity (Btu/hr)

Note: Including room air conditioners and room air conditioner heat pumps,

Source: California Appliance Efficiency Regulations Title 20, Table B-3, the Energy Code Table 110.2-E

O. Gas and Oil-Fired Furnaces

The *Appliance Efficiency Regulations* require gas- and oil-fired central furnaces with outputs less than 225,000 Btu/hr to be rated according to the associated annual fuel utilization efficiency (AFUE). Gas- and oil-fired central furnaces with outputs greater than or equal to 225,000 Btu/hr are rated according to the respective thermal (or steady-state) efficiency.

Equipment with outputs less than 225,000 Btu/hr is listed in Table E-6 of the *Appliance Efficiency Regulations* and incorporated in Table 11-31. Efficiency for equipment with outputs greater than or equal to 225,000 Btu/hr is listed in Table E-6 of the *Appliance Efficiency Regulations* and included in Appendix B.

Table 11-31: Minimum Efficiency for Gas- and Oil-Fired Central Furnaces

Appliance	Rated Input (Btu/h)	AFUE
Weatherized gas central furnaces with single phase electrical supply	< 225,000	81
Non-weatherized gas central furnaces with single phase electrical supply	< 225,000	80
Weatherized oil central furnaces with single phase electrical supply	< 225,000	78
Non-weatherized oil central furnaces with single phase electrical supply	< 225,000	83

Source: California Appliance Efficiency Regulations Title-20 - Table E-6

Noncentral gas furnaces and space heaters must be certified to have AFUE values greater than or equal to those listed in Table 11-32.

Table 11-32: Minimum Heating Efficiency for Nonducted, Noncentral, Gas-Fired Heating Equipment

Type	Capacity	AFUE
Wall Furnace (fan type)	≤ 42,000 Btu/h	75%
Wall Furnace (fan type)	> 42,000 Btu/h	76%
Wall Furnace (gravity type)	≤ 27,000 Btu/h	65%
Wall Furnace	> 27,000 to ≤ 46,000 Btu/h	66%

Type	Capacity	AFUE
(gravity type)		
Wall Furnace (gravity type)	> 46,000 Btu/h	67%
Floor Furnace	≤ 37,000 Btu/h	57%
Floor Furnace	> 37,000 Btu/h	58%
Room Heater	≤ 20,000 Btu/h	61%
Room Heater	> 20,000 to ≤ 27,000 Btu/h	66%
Room Heater	> 27,000 to ≤ 46,000 Btu/h	67%
Room Heater	> 46,000 Btu/h	68%

Source: California Appliance Efficiency Regulations Title 20 - Table E-2

P. Gas- and Oil-Fired Central Boilers and Electric Boilers

Gas- and oil-fired central boilers must be certified to have and AFUE or combustion efficiency equal to or better than those listed in the Energy Code Table 110.2-J.

11.5.3.3 Dwelling Unit Controls

§110.2 (b) & (c), §160.3(a)1

The Energy Code includes a mandatory requirement for thermostat controls. Unless controlled by a central energy management control system the thermostat must have setback capabilities. An exception is allowed only if the system is one of the following non-central types:

- Non-central electric heaters such as mini-split heat pumps
- Room air conditioners
- Room air conditioner heat pumps
- Gravity gas wall heaters
- Gravity floor heaters
- Gravity room heaters
- Wood stoves
- Fireplace or decorative gas appliances

When it is required, the setback thermostat must have a clock or other mechanism that allows the resident to schedule the heating and/or cooling set points for at least four periods over 24 hours.

If more than one piece of heating or cooling equipment is installed in a dwelling unit, the setback requirement may be met by controlling all heating or cooling units by one thermostat or by controlling each unit with a separate thermostat. Separate heating or cooling units may be provided with a separate on/off control capable of overriding the thermostat.

Thermostats for heat pumps equipped with supplementary electric resistance heat must be thermostats that minimize the use of supplementary electric resistance heating during startup and recovery from setback, as discussed in Heat Pump System Controls.

Example 11-27

Question

Am I exempt from the requirement for a thermostat if I have a packaged terminal air conditioner or heat pump or any of the equipment types listed in the exception to §110.2(c)?

Answer

Yes.

11.5.3.4 Heat Pump System Controls

§160.3(a)2C, §110.2(b), Exceptions to §110.2(b), §110.2(c), Exception to §110.2(c)

Heat pump systems must be controlled by a central energy management control system (EMCS) or by a setback thermostat as described under Dwelling Units Controls. Any heat pump with supplementary electric resistance heating requires controls with capabilities to limit the electric resistance heating. The first required capability is to set the cut-on and cut-off temperatures for the heat pump and supplementary electric resistance heating at different levels.

For example, if the heat pump begins heating when the inside temperature reaches 68°F, the electric resistance heating may be set to come on if the temperature goes below 65°F if the heat pump alone could not maintain the set point of 68°F. Also, there must be an OFF mode that automatically shuts off the electric resistance when the inside temperature reaches 68°F.

The second control capability must prevent the supplementary electric resistance heater from operating if the heat pump alone can meet the heating load, except during defrost. There is a limited exception to this second function for “smart thermostats” that provide intelligent recovery, staging, ramping, or another control mechanism that prevents the unnecessary operation of supplementary electric resistance heating when the heat pump alone can meet the heating load.

To meet the thermostat requirements, a thermostat for a heat pump with supplementary electric resistance heating must be a thermostat that minimizes the use of supplementary heating during startup and recovery from setbacks.

Note: Room air conditioner heat pumps are not required to comply with the thermostat requirements.

11.5.3.5 Equipment Sizing

§160.3 (b)1 and 2

The Energy Code does not set limits on the sizing of heating and cooling equipment, but does require that heating and cooling loads be calculated for new HVAC systems. Oversized equipment typically operates less efficiently and can create comfort problems due to excessive cycling and improper airflow. Ducts must be sized correctly, otherwise the system airflow rate may be restricted, adversely affecting the efficiency of the system and preventing the system from meeting the mandatory minimum airflow rate requirements.

Acceptable load calculation procedures include methods described in the following publications:

- The ASHRAE Handbook – Equipment
- The ASHRAE Handbook – Applications
- The ASHRAE Handbook – Fundamentals
- The SMACNA Residential Comfort System Installation Standards Manual
- ACCA Manual J

The Energy Code requires that the outdoor design conditions for heating load calculations be selected from JA2 and that the indoor design temperature for heating load calculations be 68°F. The outdoor design temperature must be no lower than the "heating winter median of extremes," as listed in JA2. The outdoor design conditions for cooling load calculations must be selected from JA2, Table 2-3, using values no greater than the "1.0 percent cooling dry bulb" and "mean coincident wet bulb" values listed. The indoor design temperature for cooling load calculations must be 75°F.

If the actual city location for a project is not included in JA2, or if the data given for a particular city do not match the conditions at the actual site as well as that given for another nearby city, consult the local building department for guidance.

The load calculations must be submitted with the compliance documentation when requested by the building department.

The load calculations may be prepared by 1) a mechanical engineer, 2) the mechanical contractor who is installing the equipment or 3) someone who is qualified to do so in the State of California according to Division 3 of the Business and Professions Code.

The Business and Professions Code does not prohibit an unlicensed person from preparing plans, drawings, or specifications for certain buildings containing no more than four dwelling units of wood-frame construction and not more than two stories and basement in height.

11.5.3.6 Standby Losses and Pilot Lights

§110.5 and §110.2(d)

Fan-type central furnaces may not have a continuously burning pilot light. This requirement does not apply to wall furnaces, floor furnaces, or any gravity-type furnace. Household cooking appliances also must not have a continuously burning pilot light, except for those without an electrical supply voltage connection and in which each pilot consumes less than 150 Btu/h.

Larger gas-fired and oil-fired forced air furnaces with input ratings equal to or greater than 225,000 Btu/h (which is bigger than a typical residential furnace) must also have an intermittent ignition device and either power venting or a flue damper.

A vent damper is an acceptable alternative to a flue damper for furnaces where combustion air is drawn from the conditioned space. All furnaces with input ratings equal to or greater than 225,000 Btu/h, including electric furnaces, that are not within the conditioned space must have jacket losses not exceeding 0.75 percent of the input rating.

11.5.3.7 Pipe Insulation

§160.3(b)6, §160.3(c)1

Specific insulation requirements for heating and cooling system piping in dwelling units are the same as requirements in common use areas. These requirements are detailed in Chapter 11.1.18.1, Chapter 4.5, and Tables 4-15a through 4.15f.

For air conditioners and heat pumps, two refrigerant lines connect the indoor and outdoor units of split-system air conditioners and heat pumps: the liquid line (the smaller diameter line) and the suction line (the larger diameter line). If the liquid line is at an elevated temperature relative to outdoor and indoor temperatures, it should not be insulated. In those areas, heat escaping from it is helpful.

The suction line carries refrigerant vapor that is cooler than ambient in the summer and (with heat pumps) warmer than ambient in the winter. This line must be insulated to the required thickness (in inches).

Insulation used for refrigerant suction lines located outside of conditioned space must include a Class I or Class II vapor retarder. The vapor retarder and insulation must be protected from physical damage, UV deterioration, and moisture with a covering that can be removed for equipment maintenance without destroying the insulation. Insulation is typically protected by aluminum, sheet metal jacket, painted canvas, or plastic cover. Adhesive tape should not be used as insulation protection because removal of the tape will damage the integrity of the original insulation during preventive maintenance. See Figure 11-34 for example of refrigerant line insulation.

Figure 11-34: Refrigerant Line Insulation

Source: Airex Manufacturing Inc.

11.5.3.8 Outdoor Condensing Units

§160.3 (b)3.

Any obstruction of the airflow through the outdoor unit of an air conditioner or heat pump lowers efficiency. Dryer vents are prime sources for substances that clog outdoor coils and sometimes discharge substances that can cause corrosion. Therefore, condensing units must not be placed within five ft. of a dryer vent. This requirement is applicable to new installations and to replacements. Regardless of location, condenser coils should be cleaned regularly. The manufacturer installation instructions may include requirements for minimum horizontal and vertical distance to surrounding objects that should be met if greater than the minimum distance required by the Energy Code. Figure 11-35 shows an example when a condensing unit installed location does not meet the clearance requirement.

Figure 11-35: Noncompliant Condensing Unit Clearance from Dryer Vents

Source: California Energy Commission

Liquid line filter driers are components of split system air-conditioners and split system heat pumps that are installed in the refrigerant line to remove moisture and particles from the refrigerant stream. These contaminants may be introduced in the refrigerant as a result of improper flushing, evacuation, and charging procedures, causing the efficiency and capacity of the air conditioner to be impaired or damaging components. If required by manufacturer's instructions, liquid line filter dryers must be installed. Sometimes, liquid line filter dryers are preinstalled by manufacturers within condensing units. Some manufacturers install liquid line filter dryers outside condensers, so they can be easily serviced by technicians and more easily verified by HERS Raters.

The quality of the filter dryer installation impacts the effectiveness of the liquid line filter dryer, as some liquid line filter dryers can be installed without regard to the direction of refrigerant flow. Heat pumps, for example, allow refrigerant flow in both directions. However, in other air conditioners where refrigerant flow occurs in only one direction, correct orientation of the liquid line filter dryer is important.

11.5.3.9 Dwelling Unit Prescriptive Requirements

§170.2(c)3

Prescriptive compliance requires the installation of a heat pump for dwelling units in buildings up to three habitable stories in Climate Zones 1-15. For Climate Zone 16, the installation of an air conditioner with gas-fired furnace is prescriptively required. For buildings with four or more habitable stories, prescriptive compliance requires installation of a heat pump for Climate Zones 2-15. For Climate Zone 1 and 16, prescriptive compliance requires the installation of a dual-fuel heat pump that uses gas as supplemental heat.

In addition, for buildings with three habitable stories in Climate Zones 4-10, see Chapter 11.4.2.2 for ventilation fan power requirements.

When using the prescriptive compliance approach, the installed heat pump or gas heating system gets no additional credit for higher efficiency equipment.

Prescriptive requirements for air-cooled air conditioners and air-source heat pumps installed in Climate Zones 2 and 8 through 15 necessitate the installation of a measurement access hole (MAH), refrigerant charge verification (RCV), and minimum system airflow verification. The minimum system airflow installation and RCV must be performed by the installer and/or HERS Rater or ATT. The MAH provides a nonintrusive means of measuring return air temperature, which is an important parameter to the RCV process. The alternative to RCV by a HERS Rater is the installation of a refrigerant FID. When installing an FID, the installer must still perform RCV.

11.5.3.10 Dual-fuel Heat Pump System

For Climate Zones 1 and 16, the prescriptive requirement includes the use of a dual-fuel heat pump for buildings four habitable stores or greater. This system pairs an electric heat pump with a gas-fired furnace and alternates between the two fuel sources for heating. Heat pumps face a challenge in colder climates where their capacity for providing heat and the efficiency of the equipment reduces as the outdoor temperature drops. This is especially true for the type of minimal efficiency heat pumps that are the basis for the federal appliance standards for heat pumps. To address these challenges, gas-fired furnace can be used for space heating when outdoor air temperature is below a certain threshold, normally between 35-45°F.

The dual-fuel heat pump system can be controlled similarly to a heat pump with electric resistance required by §110.2(b). The control should have the capability to set the cut-on and cut-off temperatures for the heat pump and supplementary gas-fired heating at different levels. For example, if the heat pump begins heating when the inside temperature reaches 68°F, the gas-fired furnace heating may be set to come on if the temperature goes below 65°F, if the heat pump alone could not maintain the set point of 68°F. Also, there must be an OFF mode that automatically shuts off the gas-fired heating when the inside temperature reaches 68°F. The system may also have a control capability that prevents the supplemental gas-fired furnace from operating if the outdoor air temperature is above a pre-set threshold.

11.5.3.11 Supplemental Heating System

Supplemental heating systems are allowed prescriptively, and the designer may elect to provide supplemental heating to a space such as a bathroom. In this instance, the supplemental heating system must be installed in a space that is served by the primary heating system and must have a thermal capacity of less than 2 kilowatts (kW) or 7,000 Btu/h while being controlled by a time-limiting device not exceeding 30 minutes. Electric resistance and electric radiant heating installation are not allowed as the primary heating system when using the prescriptive compliance method.

Example 11-28: Compliance Using the Prescriptive Approach

Question

We are designing a 3-story multifamily building in Climate Zone 4, and we want to comply with Title 24 prescriptively, can we use air conditioners for dwelling unit space cooling and gas-fired furnace for space heating? What if we have a project in Climate Zone 16?

Answer

No for Climate Zone 4. To comply with Title 24 prescriptively, the dwelling unit space heating and cooling must be provided by heat pump systems. In addition, if balanced ventilation without heat or energy recovery, the combine supply and exhaust fan rated efficacy must be 0.4W/CFM or less.

Yes, for Climate Zone 16. To comply prescriptively, air conditioner and gas-fired furnace must be used for dwelling unit space cooling and heating.

Example 11-29

Question

We are designing a 4-story multifamily building in Climate Zone 1. Can we use air conditioners for dwelling unit space cooling and gas-fired furnace for space heating?

Answer

No. To comply with Title 24 prescriptively, the dwelling unit space heating and cooling must be provided by dual-fuel heat pump systems.

11.5.3.12 Measurement Access Hole

The MAH provides a nonintrusive means for refrigerant charge verification by HERS Raters or ATT and other third-party inspectors. They eliminate the need for raters/inspectors to drill holes into the installed air conditioning equipment enclosures to place the temperature sensors that are required by the refrigerant charge verification test procedures described in the Reference Residential Appendix RA3.2.

Installation of MAH must be performed by the installer of the air conditioner or heat pump equipment according to the specifications given in Reference Residential Appendix RA3.2.

The MAH feature consists of one 5/8-inch (16 millimeters [mm]) diameter hole in the return plenum, upstream from the evaporator coil. (See Figure RA3.2-1 in Reference Residential Appendix RA3.2.)

11.5.3.13 Refrigerant Charge Verification

The prescriptive standards for Climate Zones 2 and 8-15 require all cooling systems— including ducted air-cooled air conditioners, ducted air-source heat pumps, small-duct high-velocity systems, and mini-split systems — to have the correct refrigerant charge verified. Verification of refrigerant charge must be conducted by a HERS Rater for multifamily buildings with up to three habitable stories. For multifamily buildings with four or more stories, testing only needs to be conducted and certified by the installing contractor, and neither a HERS Rater nor registration with a HERS Provider is required. The RCV procedures are documented in Reference Residential Appendix RA1.2, RA2.4.4, and RA3.2.

Refrigerant charge refers to the actual amount of refrigerant present in the system. Excessive refrigerant charge (overcharge) reduces system efficiency and can lead to premature compressor failure. Insufficient refrigerant charge (undercharge) also reduces system efficiency and can cause compressors to overheat. Ensuring correct refrigerant charge can significantly improve the performance of air-conditioning equipment. Refrigerants are the working fluids in air-conditioning and heat-pump systems that absorb heat energy from one area (through the evaporator), transfer, and reject it to another (through the condenser).

Verification of proper refrigerant charge must occur after the HVAC contractor has installed and charged the system in accordance with the manufacturer's specifications. The procedure requires properly calibrated digital refrigerant gauges, thermocouples, and digital thermometers. When multiple systems in the same dwelling unit require testing, test each system.

In a typical cooling system, there are two important performance criteria that are relatively easy to verify that there is neither too much nor too little refrigerant in the system. In systems with a fixed-orifice device in the evaporator coil, the number to check is called the *superheat*. In a system with a variable-metering device, the number to check is called the *subcooling*.

Superheat refers to the number of degrees the refrigerant is raised after it evaporates into a gas. This occurs inside the evaporator coil (or *indoor coil*). The correct superheat for a system will vary depending on certain operating conditions. The target superheat for a system must be obtained from a table provided in the RA3.2 protocols or the manufacturer's superheat table. There is an allowed range of several degrees between the measured superheat and the target superheat for a system to pass.

Subcooling refers to the number of degrees the refrigerant is lowered after it condenses into a liquid. This occurs inside the condenser coil (or *outdoor coil*). The manufacturer specifies the correct subcooling for a system. It may vary depending on operating conditions. Like superheat, there is an allowed range of several degrees between the measured subcooling and the target subcooling for a system to pass.

The temperature at which a refrigerant condenses or evaporates is called the *saturation temperature*. Above the saturation temperature, a refrigerant is always a gas. Below the saturation temperature, a refrigerant is always a liquid.

Saturation is when a refrigerant exists as both a liquid and a gas. It always occurs at the same temperature, depending on what the pressure of the refrigerant happens to be. At higher pressures, the saturation temperature goes up and vice versa. This convenient property is what makes refrigeration work.

The saturation temperature can be determined by simply measuring the pressure of a refrigerant and referring to a table, known as a *pressure-temperature* (PT) *table*, for that specific refrigerant. Saturation temperatures are well-documented for all common refrigerants.

Because variable refrigerant metering devices are prone to failure and even more so to improper installation, it is important that the operation of these devices be checked. A metering device maintains a relatively constant superheat over a wide range of operating conditions; therefore, checking the superheat, in addition to the other tests performed, will indicate if the metering device is operating correctly.

Unfortunately, checking superheat and subcooling can be done only under certain indoor and outdoor conditions. This verification procedure, called the Standard Charge Verification Method, is very weather-dependent.

There is another way to verify proper refrigerant charge that is not weather–dependent, and that is by weighing the refrigerant. Called the Weigh-in Charge Verification Method, this approach can be performed only by the installer. It can be verified by the HERS Rater either by simultaneous observation or by using the standard method when conditions permit.

11.5.3.14 Minimum System Airflow Verification for Refrigerant Charge Verification

To have a valid charge test, the system airflow must be verified to be at least 300 CFM/ton for altered systems and 350 CFM/ton for new systems. The procedures for measuring total system airflow are found in RA3.3. They include plenum pressure matching using a fan flow meter, a flow grid, a powered flow hood, and the traditional (nonpowered) flow hood. The airflow verification procedures for refrigerant charge verification no longer include the temperature split method.

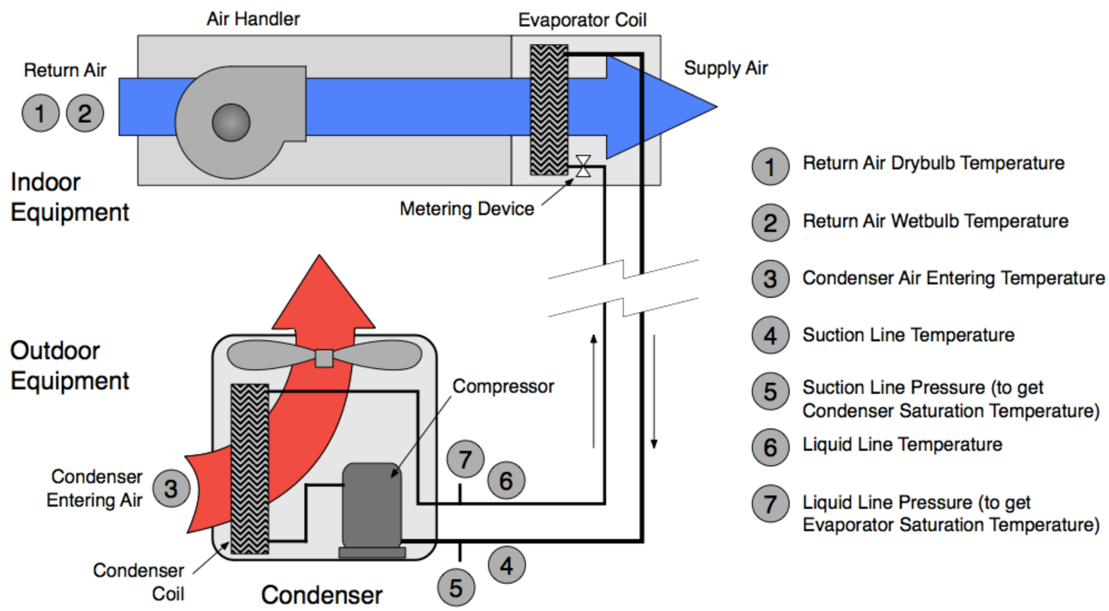
If an altered system does not meet the minimum airflow requirements, remedial steps are required to increase system airflow. More airflow is generally better for systems with air conditioning. Not only does this allow proper refrigerant charge to be verified, but it improves the overall performance of the system. When able to be performed on a system, regardless of the refrigerant charge verification procedure, minimum system airflow must always be verified.

In some alterations, improving airflow may be cost-prohibitive, and there is a process for documenting this (RA3.3.3.1.5). When this option is used, verification by sample groups is not allowed. Minimum airflow is critical to proper air-conditioner operation. Reducing airflow reduces cooling capacity and efficiency. Many systems in California have oversized equipment and undersized ducts. In newly installed duct systems, the minimum airflow requirement is higher because the opportunity exists to design and install a better system. In altered systems, the installer may be required to modify the ducts system to meet the minimum airflow. The minimums of 300 and 350 CFM/ton are lower than the desired airflow for most systems, which is usually 400 CFM/ton and higher.

11.5.3.15 Standard Charge Verification Procedure (RA3.2.2)

The first step is to turn on the air-conditioning system and let it run for at least 15 minutes to stabilize temperatures and pressures. While the system is stabilizing, the HERS Rater or the installer may attach the instruments needed to take the measurements.

Figure 11-39: Measurements for Refrigerant Charge and Airflow Tests



Source: California Energy Commission

The following measurements must be taken by the technician or HERS Rater, when applicable.

1. The return air wet bulb and dry bulb temperatures are measured in the return plenum before the blower at the location labeled "Title 24 – Return Plenum Measurement Access Hole." This hole must be provided by the installer, not the rater (See Points 1 and 2 in Figure 11-39). See Figure RA 3.2-1 for more information on the placement of the measurement access hole (MAH).
2. Moreover, the outdoor air dry bulb temperature is measured at the point where the air enters the outdoor condensing coil. (See Point 3 in Figure 11-39). It is important that this outdoor temperature sensor be shaded from direct sun during the verification procedure.

In addition to the air temperature measurements, four refrigerant properties need to be measured. Two of these measurements are taken near the suction line service valve before the line enters the outdoor unit and are used to check the superheat.

1. The first measurement is the temperature of the refrigerant in the suction line, which is taken by a clamp-on thermocouple or other suitable device insulated from the outdoor air. (See Point 4 in Figure 11-39.)
2. The second measurement determines the saturation temperature of the refrigerant in the evaporator coil. (See Point 5 in Figure 11-39.) The saturation temperature can be determined from the low-side (suction line) pressure and a saturation temperature table for the applicable refrigerant.

To check the subcooling, two more refrigerant properties are required and may be measured near the liquid line service valve at the point where the line exits the outdoor unit.:

1. The liquid refrigerant temperature in the liquid line is measured by a clamp-on thermocouple insulated from the outdoor air. (See Point 6 in Figure 11-39.)
2. The condenser saturation temperature can be determined from the liquid line pressure and a saturation temperature table for the applicable refrigerant. (See Point 7 in Figure 11-39.)

Determination of the condenser saturation temperature and the liquid line temperature is used only for the subcooling verification method on systems with TXV or EXV metering devices.

11.5.3.16 Superheat Charge Verification Method (RA3.2.2.6.1)

The *Superheat Charge Verification Method* is used on units with a fixed-orifice refrigerant metering device (not a TXV or EXV).

Airflow verification must be confirmed before starting the Superheat Verification Method.

The *Superheat Verification Method* compares the actual (measured) superheat temperature to a target value from a table. The actual superheat temperature is the measured suction line temperature ($T_{Suction,\ db}$) minus the evaporator saturation temperature ($T_{Evaporator,\ Saturation}$). The target superheat value is read from a table (Table RA3.2-2 or the manufacturer's superheat table).

Only an EPA-certified technician may add or remove refrigerant. Under no circumstances may HERS Raters add or remove refrigerant on systems that they are verifying.

11.5.3.17 Subcooling Verification Method (RA3.2.2.6.2)

The *Subcooling Verification Method* is used on units with a variable refrigerant metering device (a TXV or EXV).

Airflow verification must be confirmed before starting the Subcooling Verification Method.

The *Subcooling Verification Method* compares the actual subcooling temperature to the target value supplied by the manufacturer. The actual subcooling is the condenser saturation temperature ($T_{Condenser,\ Saturation}$) minus the liquid line temperature (T_{Liquid}).

11.5.3.18 Weigh-In Charging Procedure (RA3.2.3)

The weigh-in charging procedure charges the system by determining the appropriate weight of refrigerant based on the size of the equipment and refrigerant lines rather than by measuring steady-state performance of the system. Systems using the weigh-in procedure to meet the refrigerant charge verification requirement may not use group sampling procedures for HERS verification compliance.

The weigh-in procedure does not relieve the installer of the responsibility to comply with the required minimum system airflow.

There are two installer options for completing the weigh-in procedure. One involves adjusting the amount of refrigerant supplied by the manufacturer in a new system, as specified by the manufacturer (weigh-in charge adjustment). The other involves evacuating the entire system and recharging it with the correct total amount of refrigerant, by weight (weigh-in total charge).

The weigh-in charge adjustment procedure may be used only when a new factory-charged outdoor unit is being installed and the manufacturer provides adjustment specifications based on evaporator coil size and refrigerant line size and length.

The weigh-in total charge may be used for any weigh-in procedure but still requires manufacturer's adjustment specifications. Only the installer/technician may perform any kind of weigh-in procedure.

11.5.3.19 Equipment Limitations

The Energy Code specifically requires verification of refrigerant charge only for air-cooled air conditioners and air-source heat pumps. All other types of systems are not expressly exempt from the refrigerant charge requirements. Certain portions of the requirements may still apply, such as the minimum system airflow requirement. The installer would have to confirm with the manufacturer and the CEC. The installer must adhere strictly to the manufacturer's specifications.

Variable refrigerant flow systems and systems such as some mini-split systems that cannot be verified using the standard charge verification procedure in RA3.2.2 must demonstrate compliance using the weigh-in method. Verification by the HERS Rater can be accomplished only by simultaneous observation of the installer's weigh-in as specified by RA3.2.3.2, and only if use of HERS Rater observation procedure is specified by the Energy Code.

11.5.3.20 HERS Verification Procedures

When required by the CF1R, HERS Raters must perform field verification and diagnostic testing of the refrigerant charge, including verification of minimum system airflow and verification of installation of the measurement access hole.

The verification procedures are essentially identical for the rater and the installer except that the tolerances for passing the superheat and subcooling tests are less stringent for the rater's test. This is to allow for some variations in measurements due to instrumentation or test conditions (for example, weather).

The following conditions prohibit verification using sample groups:

1. When the weigh-in method is used

2. When the minimum airflow cannot be met despite reasonable remediation attempts. (See RA3.3.3.1.5).

As always, to be eligible for sampling, the installer must first verify and pass the system. If sampling is not being used, the rater will perform the verification only after the installer has charged the system according to manufacturer’s specifications.

11.5.3.21 Winter Setup Procedures

Reference Appendix RA1 provides for the approval of special case refrigerant charge verification procedures. These protocols may be used only if the manufacturer has approved use of the procedure for their equipment.

One such procedure is found in RA1.2 Winter Setup for the standard charge verification procedure (winter charge setup). It provides for a modification to the standard charge procedure when temperature conditions do not allow use of the RA3.2.2 standard charge verification procedure.

The winter charge setup allows both installers and HERS Raters to verify the charge when outdoor temperatures are below the manufacturer's allowed temperature, or the outdoor temperature is less than 55°F. The Weigh-in Charging Procedure specified in RA3.2.3 may also be used when the outdoor temperatures are below the manufacturer's allowed temperature or below 55°F but may be used only by the installer.

The winter charge setup procedure allows the system to operate in the same range of pressure differences between the low-side pressure and the high-side pressure as occurs during warm outdoor temperatures, by restricting the airflow at the condenser fan outlet. The winter charge setup is used only for units equipped with variable metering devices, which include thermostatic expansion valves (TXV) and electronic expansion valves (EXV) for which the manufacturer specifies subcooling as the means for determining the proper charge for the unit, including units equipped with microchannel heat exchangers. Once this pressure differential is achieved, the variable metering device calculations are conducted in the same way as the variable metering device procedures described in RA3.2.2.6.2. All other applicable requirements in RA3.2.2 remain the same and must be completed when using the winter charge setup.

Though not specifically mentioned in the FID protocols in Residential Appendix RA3.4.2, the RA 1.2 winter setup method may be used if applicable. Thus, for FID verification, the winter setup method may be used in place of the subcooling method.

11.5.3.22 Using Weigh-In Charging Procedure at Low Outdoor Temperatures

When a new HVAC system is installed, the HVAC installer must check the refrigerant charge, and a HERS Rater must verify the correct charge; however, an exception to §150.1(c)7A provides for an alternative third-party HERS verification if the weigh-in method is used when the outdoor temperature is less than 55 degrees F.

Typically, when the weigh-in method is used by the installing contractor, a HERS Rater must perform a charge verification in accordance with the RA3.2. standard charge procedure. However, because the RA3.2.2 procedures cannot be used when the outdoor temperatures are less than 55 degrees, the Energy Code provides the installer with two choices:

1. Use the RA3.2.3.1 Installer Weigh-In Charging Procedure to demonstrate compliance and install an occupant-controlled smart thermostat (OCST)**.**
2. Wait for warmer temperatures then perform the standard charge verification procedure. In this case, the installer must agree to return to correct refrigerant charge if a HERS Rater determines later, when the outside temperature is 55 degrees F or above, that correction is necessary as described in Residential Appendix RA2.4.4. The installer must also provide written notice to the owner and enforcement agency that the charge has not yet been verified. An example owner's notification is shown in Figure 11-40.

Figure 11-40: Example of Notification to Owners of Delayed Charged Verification

Note to Owner: We're not done yet!

Congratulations on your new Air-Conditioning System! Your new system is more efficient than older systems and it has been installed to industry guidelines, ensuring many years of comfort and efficient service.

One thing you to know, however, is that the installation process is not complete! Because your unit was installed when the outside air temperature too low to fine tune the air conditioner, the unit must be serviced and verified when the weather is warmer.

This requires your cooperation. You need to allow access to the unit for your Installer and/or HERS Rater (verifier) to verify that the airflow is set correctly. Your project is not considered finished until this verification takes place. If it is not done, **your unit may cost more to operate, may not heat and cool as effectively and may not last as long.**

You will be contacted within the next few months to schedule this service. If you do not hear something after a few months of warmer weather, please contact your Installer. Enjoy your new system!

Source: California Energy Commission

11.5.3.23 Minimum System Airflow

Ducted forced-air cooling systems must comply with the minimum system airflow rate of greater than or equal to 350 CFM/ton, or 250 CFM/ton for small duct, high velocity systems, when performing the refrigerant charge verification. The airflow is important when performing the refrigerant charge verification to validate the measured values for pressure and temperature. The correct airflow will also improve the performance of the air-conditioning equipment.

The airflow verification procedure is documented in Reference Residential Appendix RA3.3.

11.5.3.24 Fault Indicator Display (FID)

The installation of an FID may be used as an alternative to the prescriptive requirement for HERS diagnostic testing of the refrigerant charge in air conditioners and heat pumps. The installation of an FID does not preclude the HVAC installer from having to properly charge the system with refrigerant. The FID provides real-time information to the building occupant or operator about the status of the system refrigerant charge, metering device, and system airflow. The FID will monitor and determine the operating performance of air conditioners and heat pumps and provide visual indication to the system owner or operator if the refrigerant charge, airflow, or metering device performance of the system does not conform to approved target parameters for minimally efficient operation. Thus, if the FID signals the owner/occupant that the system requires service or repair, the occupant or operator can immediately call for a service technician to make the necessary adjustments or repairs. An FID can provide significant benefit by alerting the owner/occupant to the presence of inefficient operation that could result in excessive energy use/costs over an extended period. An FID can also indicate system performance faults that could result in system component damage or failure if not corrected, thus helping the owner/occupant avoid unnecessary repair costs.

Fault indicator display technologies are expected to be installed at the factory; otherwise, they may be installed in the field according to manufacturer's specifications. Reference Joint Appendix JA6 contains more information about FID technologies.

The presence of an FID on a system must be field-verified by a HERS Rater or ATT. See Reference Residential Appendix RA3.4.2 for the HERS verification procedure, which consists of a visual verification of the presence of the installed FID technology. The Rater must inspect to see that the visual indication display component of the installed FID technology is mounted adjacent to the thermostat of the split system. When the outdoor temperature is greater than 55°F, the Rater must also observe that the system reports no system faults when the system is operated continuously for at least 15 minutes when the indoor air temperature returning to the air conditioner is at or above 70°F. When the outdoor temperature is below 55°F, the Rater must observe that the FID performs a self-diagnosis and indicates that the sensors and internal processes are operating properly.

11.5.3.25 Dwelling Unit Performance Approach

§170.1(d)

There are several options for compliance credit related to the dwelling unit heating and cooling system through the performance approach.

11.5.3.26 High-Efficiency Heating

Heating system efficiencies are explained in Chapter 11.6.3.1 0. The minimum efficiency is required for prescriptive compliance. When the performance approach is used, additional compliance credit may be available from higher efficiency heating equipment.

When a heat pump is providing space heating, if the efficiency used for compliance is higher than the minimum required HSPF, the system efficiency must be verified by a HERS Rater. Moreover, because the capacity of the heat pump affects the amount of back-up electric resistance heating required to attain and maintain comfort conditions, if the capacity proposed for compliance is different than the default capacity used in the compliance software, the Air Conditioning, Heating, and Refrigeration Institute (AHRI) ratings for heating capacity of the installed heat pump must be verified by a HERS Rater to confirm the heating capacities at 47°F and 17°F are equal or greater than the heating capacities given on the certificate of compliance. See RA3.4.4.2 for more information about this HERS verification

11.5.3.27 High-Efficiency Air Conditioner

Savings can be achieved by choosing an air conditioner that exceeds the minimum efficiency, SEER and (or) EER, requirements.

The EER is the full-load efficiency at specific operating conditions. It is possible that two units with the same SEER can have different EERs. In cooling climate zones of California, for two units with a given SEER, the unit with the higher EER is more effective in saving energy. Using the performance approach, credit is available for specifying an air conditioner with an EER greater than the minimums identified in Chapter 11.5.3. When credit is taken for a high EER and/or SEER, field verification by a HERS Rater or ATT is required. (See Reference Residential Appendix RA3.4.4).

11.5.3.28 Central Fan Ventilation Cooling

Central fan ventilation cooling performs a function similar to a WHF using the central space-conditioning ducts to distribute outside air. There is no performance credit for central fan ventilation cooling because the compliance software does not include it as an option.

11.5.3.29 Zonal Control

A credit is provided for zoned heating systems, which save energy by providing selective conditioning for only the occupied areas of a dwelling unit. A dwelling unit having at least two zones (living and sleeping) may qualify for this compliance credit. The equipment may consist of one heating system for the living areas and another system for sleeping areas or a single system with zoning capabilities, set to turn off the sleeping areas in the daytime and the living area unit at night. This compliance credit is not commonly applied in multifamily buildings.

There are unique eligibility and installation requirements for zonal control to qualify under the Energy Code. The following steps must be taken for the building to show compliance with the Energy Code under this exceptional method:

1. **Temperature Sensors**. Each thermal zone, including a living zone and a sleeping zone, must have air temperature sensors that provide accurate temperature readings of the typical condition in that zone.
2. **Habitable Rooms**. For systems using central forced-air or hydronic heating, each habitable room in each zone must have a source of space heating, such as forced-air supply registers, radiant tubing, or a radiator. For systems using a combination of a central system and a gas-vented fireplace or other conditioning units, the zone served by the individual conditioning unit can be limited to a single room. Bathrooms, laundry, halls and/or dressing rooms are not habitable rooms.
3. **Noncloseable Openings**. The total noncloseable opening area (W) between adjacent living and sleeping thermal zones (such as halls, stairwells, and other openings) must be less than or equal to 40 ft^2. All remaining zonal boundary areas must be separated by permanent floor-to-ceiling walls and/or fully solid, operable doors capable of restricting free air movement when closed.
4. **Thermostats**. Each zone must be controlled by a central automatic dual-setback thermostat that can control the conditioning equipment and maintain preset temperatures for varying periods in each zone independent of the other. Thermostats controlling vented gas fireplace heaters that are not permanently mounted to a wall are acceptable as long as they have the dual-setback capabilities.

Other requirements specific to forced-air-ducted systems include the following:

1. Each zone must be served by a return air register located entirely within the zone. Return air dampers are not required.
2. Supply air dampers must be manufactured and installed so that when they are closed, there is no measurable airflow at the registers.
3. The system must be designed to operate within the equipment manufacturer's specifications.
4. Air is to positively flow into, though, and out of a zone only when the zone is being conditioned. No measurable amount of supply air is to be discharged into unconditioned or unoccupied space to maintain proper airflow in the system.

Although multiple thermally distinct living and/or sleeping zones may exist in a residence, the correct way to model zonal control for credit requires only two zones: a living zone and a sleeping zone. All separate living zone components must be modeled as one living zone; the same must be done for sleeping zones.

11.5.3.30 Alternative Systems

Alternative system types can comply through the performance approach. Chapter 11.6.6 describes some common alternative systems used in dwelling units and the associated code requirements.

11.5.4 Dwelling Unit Air Distribution System Ducts, Plenums, Fans, and Filters

Air distribution system performance impacts overall HVAC system efficiency. Therefore, air distribution systems are required to meet several mandatory and prescriptive requirements as discussed below.

The Energy Code requires that air distribution ducts to be sealed and tested in all climate zones. There are also several compliance credits available related to duct system design.

Duct efficiency is affected by the following parameters:

- Duct location (attic, crawlspace, basement, inside conditioned space, or other)
- Specific conditions in the unconditioned space, for example, presence of a radiant barrier
- Duct insulation characteristics
- Duct surface area
- Air leakage of the duct system

In performance calculations, duct efficiency can be calculated in one of two ways:

- Default input assumptions
- Diagnostic measurement values

The compliance software uses default assumptions for the proposed design when the user does not include improvements in duct efficiency.

11.5.4.1 Dwelling Unit Mandatory Requirements

Unless otherwise noted, the enforcement of these minimum standards is normally the responsibility of the building official. HERS Raters or ATTs may also verify compliance with these requirements in conjunction with mandatory testing.

11.5.4.2 Duct Installation Standards

§160.3(b)5A

Duct construction must comply with the California Mechanical Code Sections 601, 602, 603, 604, 605, and the applicable requirements of the Energy Code. Some highlights of these requirements are listed in this section, along with some guidance for recommended quality construction practice.

Q. Minimum Insulation

§160.3(b)5Aii

Portions of supply-air and return-air ducts and plenums that are not installed entirely in conditioned space must have an R-value of R-6. Ducts installed in conditioned space do not require insulation if the following conditions are met and verified by visual inspection by the building department:

- The non-insulated portion of the duct system is located entirely inside conditioned space within the building's thermal envelope.
- At all locations where non-insulated portions of the duct system penetrate unconditioned space, the penetration must be draft stopped compliant with California Fire Code (CFC) sections 703.1 and 704.1 and air-sealed with materials complaint with CMC section E502.4.2. All connections in unconditioned space must be insulated to at least R-6.0.

CFC Sections 703.1 and 704.1 require that materials and firestop systems used through penetrations in fire-resistance-rated construction, construction installed to resist the passage of smoke, and materials and systems used to protect joints and voids in the following locations must be maintained.

- Joints in or between fire-resistance-rated walls, floors or floor/ceiling assemblies and roof or roof/ceiling assemblies.
- Joints in smoke barriers.
- Voids at the intersection of a horizontal floor assembly and an exterior curtain wall.
- Voids at the intersection of a horizontal smoke barrier and an exterior curtain wall.
- Voids at the intersection of a nonfire-resistance-rated floor assembly and an exterior curtain wall.
- Voids at the intersection of a vertical fire barrier and an exterior curtain wall.
- Voids at the intersection of a vertical fire barrier and a nonfire-resistance-rated roof assembly.

The materials and systems must be securely attached to or bonded to the construction being penetrated or the adjacent construction, with no openings visible through or into the cavity of the construction.

CMC E502.4.2 requires that all joints, seams, and penetrations of must be made airtight by means of mastics, gasketing, or other means.

Alternatively, ducts may be uninsulated if the entire duct system is verified to be entirely in conditioned space as defined in §100.1 by visual inspection and by using the protocols of RA3.1.4.3.8. For buildings with four or more habitable stories, testing may be conducted by the installing contractor and verified by the enforcement agency field inspector. For buildings with up to three habitable stories, the testing and visual inspection must be conducted by a HERS Rater.

RA3.1.4.3.8 describes the duct leakage to outside test that determines whether the ducts are within the pressure boundary of the space being served by the duct system. A basic visual inspection of the ducts ensures that no portion of the duct system is obviously outside the apparent pressure/thermal boundary.

Leakage to outside means conditioned air leaking from the ducts to anywhere outside the pressure boundary of the dwelling unit conditioned space served by the duct system, which includes leakage to outside the building and leakage to adjacent dwelling units or other interior building spaces.

Exception to §160.3(b)5A: Ducts and fans integral to a wood heater or fireplace are exempt from §160.3(b)5A.

§160.3(b)5E

For determining the installed R-value of duct insulation based on thickness, when not an integral part of a manufacturer-labeled, insulated duct product such as vinyl flex duct, the following must be used:

- For duct wrap, the installed thickness of insulation must be assumed to be 75 percent of the nominal thickness due to compression.
- For duct board, duct liner, and factory-made rigid ducts not normally subjected to compression, the nominal insulation thickness must be used.

Example 11-30

Question

I have a five-story multifamily building with individual ducted heat pumps serving the dwelling unit. The ducts and equipment are located in a dropped soffit within conditioned space. Do I need to insulate the ducts?

Answer

No, if the duct system is entirely in the conditioned space there is no insulation requirement.

Question

What if I have the same scenario in a three-story multifamily building?

Answer

The duct system does not need to be insulated. There is a performance credit available if the ducts are tested by a HERS Rater to meet no greater than 25 CFM leakage to outside per RA3.1.4.3.8.

R. Joints

§160.3(b)5

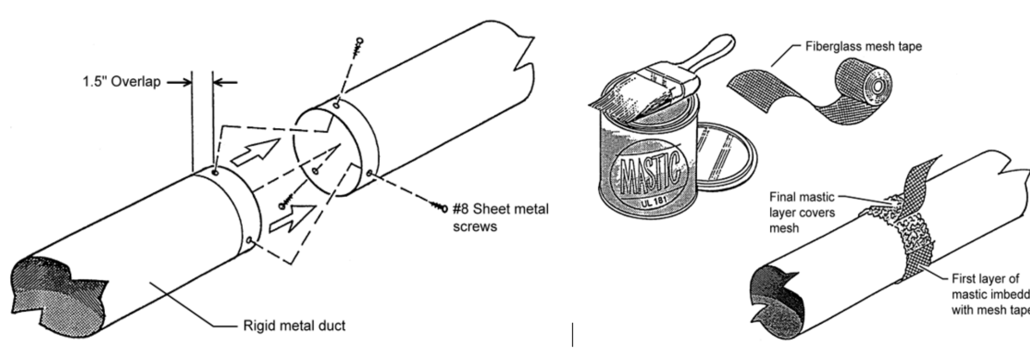
All joints must be sealed to be airtight with either mastic, tape, aerosol sealant, or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B, or UL 723. Duct systems must not use cloth-backed, rubber-adhesive duct tape regardless of UL designation, unless it is installed in combination with mastic and clamps. The CEC has approved three cloth-backed duct tapes with special butyl synthetic adhesives rather than rubber adhesive to seal flex duct to fittings. These tapes are:

1. Polyken 558CA, manufactured by Berry Plastics Tapes and Coatings Division.
2. Nashua 558CA, manufactured by Berry Plastics Tapes and Coatings Division.
3. Shurtape PC 858CA, manufactured by Shurtape Technologies, Inc.

These tapes passed Lawrence Berkeley Laboratory tests comparable to those that cloth-backed, rubber-adhesive duct tapes failed. (The LBNL test procedure has been adopted by the American Society of Testing and Materials as ASTM E2342.) These tapes are allowed to be used to seal flex duct to fittings without being in combination with mastic. These tapes cannot be used to seal other duct system joints, such as the attachment of fittings to plenums and junction boxes. These tapes have on the backing a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition) to illustrate where they are not allowed to be used, installation instructions in the packing boxes that explain how to install them on duct core to fittings, and a statement that the tapes cannot be used to seal fitting to plenum and junction box joints.

Mastic and mesh should be used where round or oval ducts join flat or round plenums. (See Figure 11-36.)

Figure 11-36: Sealing Metallic Ducts with Mastic and Mesh

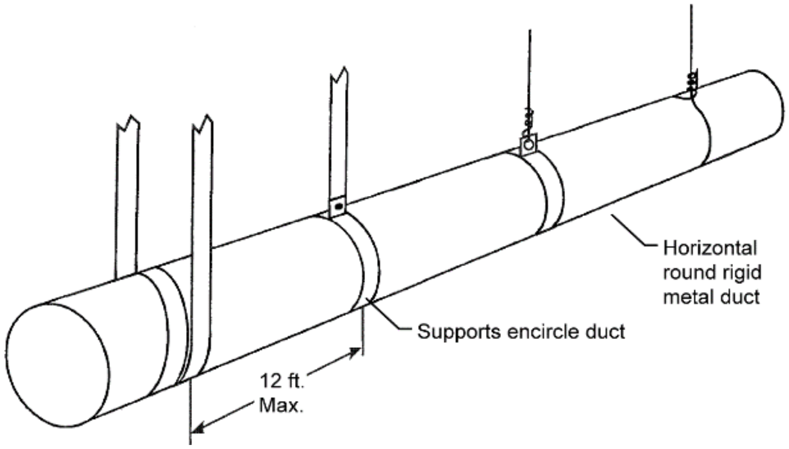


Source: Richard Heath & Associates/Pacific Gas and Electric Company

All ducts must be adequately supported. Rigid ducts and flex ducts may be supported on rigid building materials between ceiling joists or on ceiling joists.

For rigid round metal ducts that are suspended from above, hangers must occur 12 ft. apart or less (See Figure 11-37).

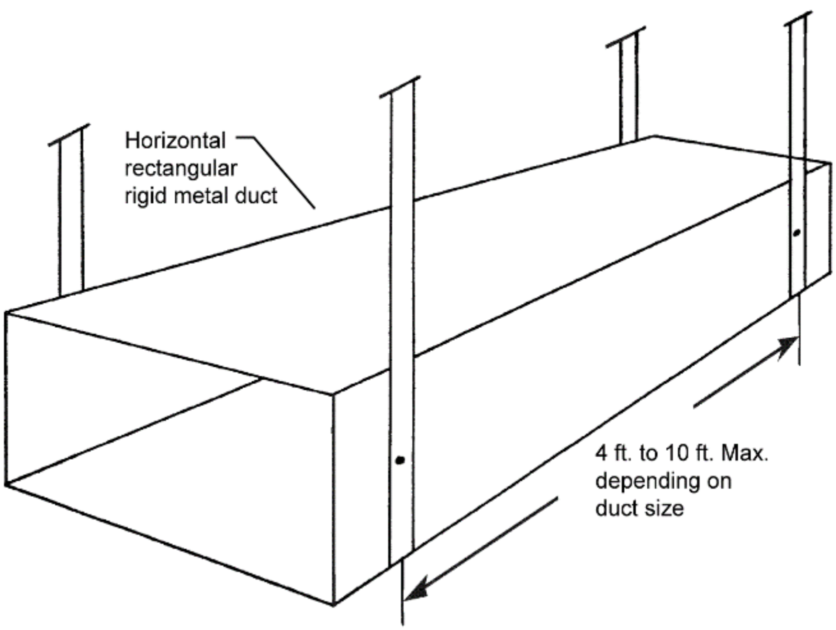
Figure 11-37: Options for Suspending Rigid Round Metal Ducts



Source: Richard Heath & Associates/Pacific Gas and Electric Company

For rectangular metal ducts that are suspended from above, hangers must occur at a minimum of 4 ft. to 10 ft., depending on the size of the ducts (refer to Figure 11-38).

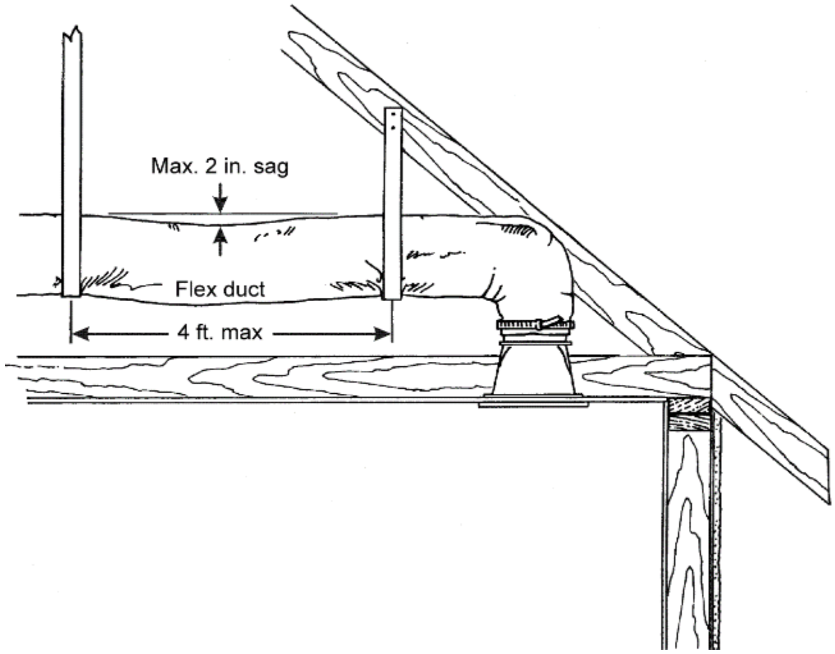
Figure 11-38: Options for Suspending Rectangular Metal Ducts



Source: Richard Heath & Associates/Pacific Gas and Electric Company

For flex ducts that are suspended from above, hangers must occur at 4 ft. apart or less, and all fittings and accessories must be supported separately by hangers (See Figure 11-39).

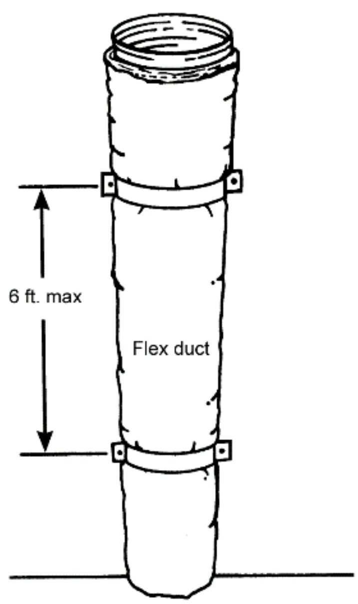
Figure 11-39: Minimum Spacing for Suspended Flex Ducts



Source: Richard Heath & Associates/Pacific Gas and Electric Company

For vertical runs of flex duct, support must occur at 6 ft. intervals or less (See Figure 11-40).

Figure 11-40: Minimum Spacing for Supporting Vertical Flex Ducts

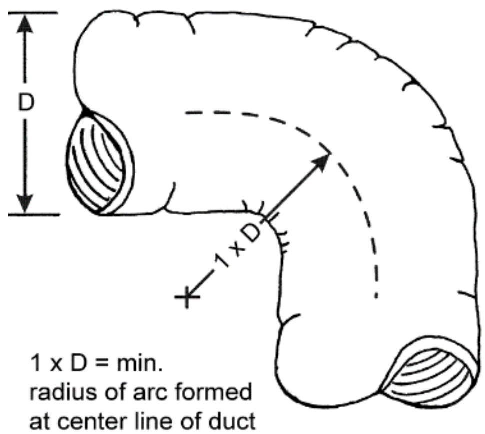


Source: Richard Heath & Associates/Pacific Gas and Electric Company

The routing and length of all duct systems can have significant effects on system performance, due to possible increased airflow resistance. The CEC recommends using the minimum length of duct to make connections and the minimum possible number of turns.

For flexible ducts, the CEC recommends fully extending the duct by pulling the duct tightly, cutting off any excess duct, avoiding bending ducts across sharp corners or compressing them to fit between framing members (See Figure 11-41) and avoiding incidental contact with metal fixtures, pipes, or conduits or installation of the duct near hot equipment such as furnaces, boilers, or steam pipes that are above the recommended flexible duct use temperature.

Figure 11-41: Minimizing Radius for Flex Duct Bends



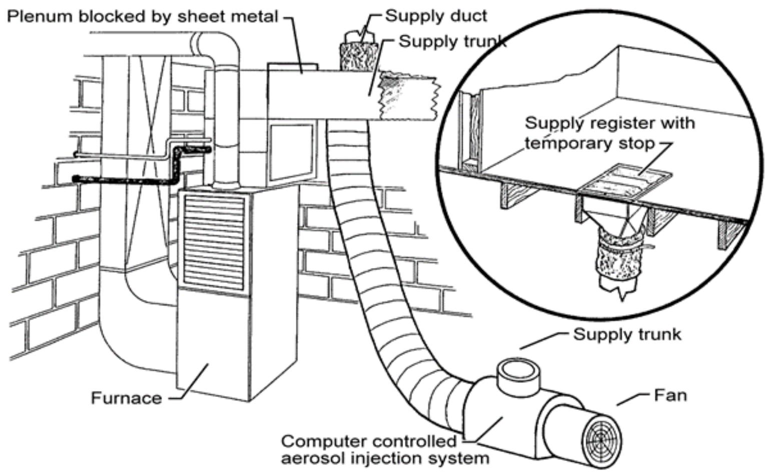
Source: Richard Heath & Associates/Pacific Gas and Electric Company

All joints between two sections of duct must be mechanically fastened and substantially airtight. For a flex duct, this must consist of a metal sleeve no less than four inches between the two sections of flex duct.

All joints must be properly insulated. For flex ducts, installers must pull the insulation and jacket back over the joint and use a clamp or two wraps of tape. Aerosol sealant injection systems are an alternative that typically combines duct testing and duct sealing in one process.

Figure 11-42 shows the computer-controlled injection fan temporarily connected to the supply duct. The plenum is blocked off by sheet metal to prevent the sealant from entering the furnace. Supply air registers are also blocked temporarily to keep the sealant out of the house. Ducts must still be mechanically fastened even if an aerosol sealant system is used.

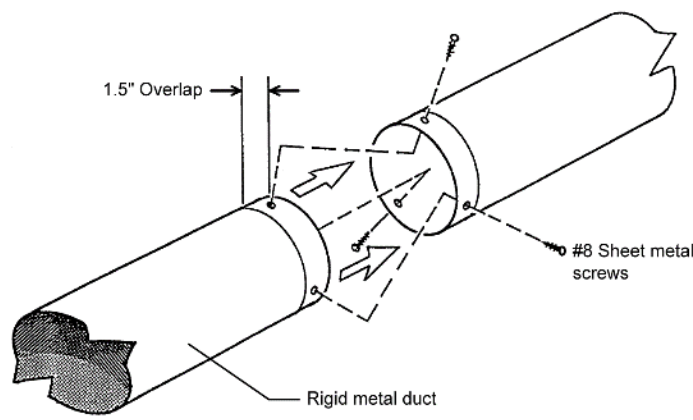
Figure 11-42: Computer-Controlled Aerosol Injection System



Source: Richard Heath & Associates/Pacific Gas and Electric Company

All joints must be mechanically fastened. For residential round metal ducts, installers must overlap the joint by at least 1½ inches and use three sheet metal screws equally spaced around the joint (See Figure 11-43).

Figure 11-43: Connecting Round Metallic Ducts

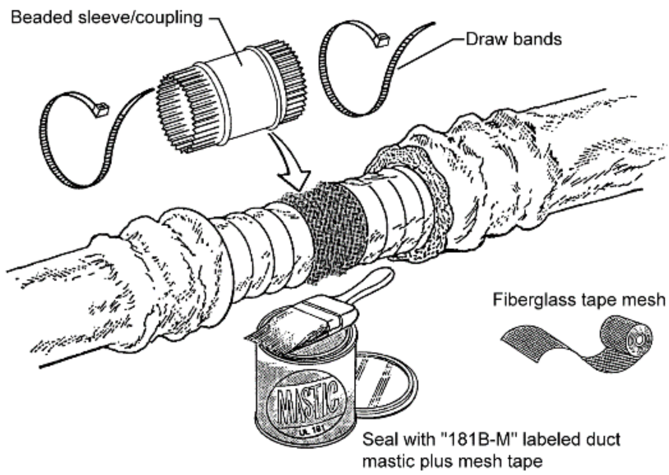


Source: Richard Heath & Associates/Pacific Gas and Electric Company

For round, nonmetallic flex ducts, installers must insert the core over the metal collar or fitting by at least one inch. This connection may be completed with either mesh, mastic and a clamp, or two wraps of tape and a clamp.

For a mesh and mastic connection, the installer must first tighten the clamp over the overlapping section of the core, apply a coat of mastic covering both the metal collar and the core by at least one inch, and then firmly press the fiber mesh into the mastic and cover with a second coat of mastic over the fiber mesh (See Figure 11-44).

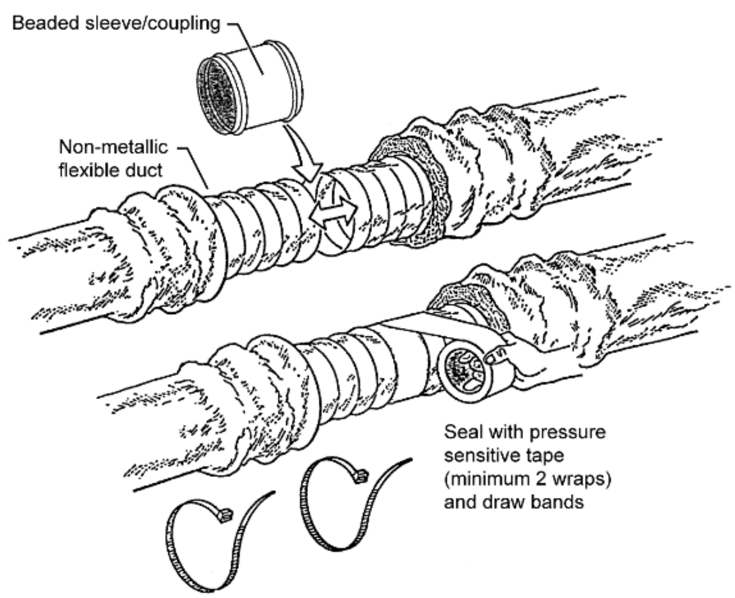
Figure 11-44: Connecting Flex Ducts Using Mastic and Mesh



Source: Richard Heath & Associates/Pacific Gas and Electric Company

For the tape connection, first apply at least two wraps of approved tape covering both the core and the metal collar by at least one inch, then tighten the clamp over the overlapping section of the core (See Figure 11-45).

Figure 11-45: Connecting Flex Ducts Using Tape and Clamps



Source: Richard Heath & Associates/Pacific Gas and Electric Company

S. Factory-Fabricated Duct Systems

§160.3(b)5B

Factory-fabricated duct systems must comply with the following requirements:

- All factory-fabricated duct systems must comply with UL 181 for ducts and closure systems, including collars, connections, and splices, and be labeled as complying with UL 181.

- All pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts must comply with UL 181 and UL 181A.
- All pressure-sensitive tapes and mastics used with flexible ducts must comply with UL 181 and UL 181B.
- Joints and seams of duct systems and related components cannot be sealed with cloth-backed rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands.
- The tape has on the backing the phrase "CEC approved," a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition), and a statement that it cannot be used to seal fittings to plenums and junction box joints.

T. Field-Fabricated Duct Systems

§160.3(b)5C

Field-fabricated duct systems must comply with the following requirements:

- Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems must comply with UL 181. All pressure-sensitive tapes, mastics, aerosol sealants, or other closure systems used for installing field-fabricated duct systems must meet the applicable requirements of UL 181, UL 181A, and UL 181B.
- Mastic sealants and mesh:
  - Sealants must comply with the applicable requirements of UL 181, UL 181A, and/or UL 181B and be nontoxic and water-resistant.
  - Sealants for interior applications must be tested in accordance with ASTM C731 and D2202.
  - Sealants for exterior applications must be tested in accordance with ASTM C731, C732, and D 2202.
  - Sealants and meshes must be rated for exterior use.
- Pressure-sensitive tapes must comply with the applicable requirements of UL 181, UL 181A, and UL 181B.
- Joints and seams of duct systems and their components must not be sealed with cloth-backed rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands.
- The tape has on the backing the phrase "CEC approved," a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition), and a statement that it cannot be used to seal fittings to plenums or junction box joints.

U. Flexible Duct Draw Bands

- Draw bands must be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties.
- Draw bands must have a minimum tensile strength rating of 150 pounds.
- Draw bands must be tightened as recommended by the manufacturer with an adjustable tensioning tool.

V. Aerosol-Sealant Closures

- Aerosol sealants must meet the requirements of UL 723 and be applied according to manufacturer specifications.
- Tapes or mastics used in combination with aerosol sealing must meet the requirements of this section.

If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape must be used.

Building spaces such as cavities between walls, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board, or flexible duct must not be used for conveying conditioned air, including return air and supply air. Using drywall materials as the interior surface of a return plenum is not allowed. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms must not be compressed to cause reductions in the cross-sectional area of the ducts. Although a HERS Rater or acceptance test technician may examine this as a part of his or her responsibilities when involved in a project, the enforcement of these minimum standards for ducts is the responsibility of the building official.

W. Product Markings

§160.3(b)5Bi, §160.3(b)5F

All factory-fabricated duct systems must meet UL 181 for ducts and closure systems and be labeled as complying with UL 181. Collars, connections, and splices are factory-fabricated duct systems and must meet the same requirement.

Insulated flexible duct products installed to meet this requirement must include labels, in maximum intervals of three ft., showing the R-value for the duct insulation (excluding air films, vapor barriers, or other duct components), based on the tests and thickness specified in §160.3(b)5D and §160.3(b)5Eiii.

X. Dampers to Prevent Air Leakage

§160.3(b)5G

Fan systems that exhaust air from the building to the outside must be provided with back draft or automatic dampers.

§160.3(b)5H

Gravity ventilating systems must have an automatic or readily accessible, manually operated damper in all openings to the outside, except combustion inlet, outlet air openings, and elevator shaft vents. This includes clothes dryer exhaust vents when installed in conditioned space.

Y. Protection of Insulation

§160.3(b)5I

Insulation must be protected from damage, including damage from sunlight, moisture, equipment maintenance, and wind, but not limited to the following:

- Insulation exposed to weather must be suitable for outdoor service, for example, protected by aluminum, sheet metal, painted canvas, or plastic cover.
- Cellular foam insulation must be protected as above or painted with a coating that is water-retardant and shields from solar radiation that can degrade the material.

Z. Porous Inner Core Flex Duct

§160.3(b)5J

Over time, the outer vapor barrier of flex duct can degrade and be easily damaged. Therefore, porous inner core flex duct must have a non-porous layer or air barrier between the inner core and the outer vapor barrier.

11.5.4.3 Duct System Sealing and Leakage Testing

§160.3(b)5K

Duct system sealing and leakage testing is mandatory in all climate zones. Duct systems in newly constructed multifamily dwellings are required to comply with the requirements regardless of the duct system location, except for buildings with four or more habitable stories in Climate Zone 1, 3, 5, and 7, which are exempt from the testing requirements. When the air-handling unit is installed and the ducts connected directly to the air handler, the total leakage of the duct system must not exceed 12% of the nominal system air handler airflow or the duct system leakage to outside must not exceed 6% of the nominal system air handler airflow.

The duct system leakage must be determined according to the applicable procedures outlined in RA3.1.4.3. Verification of duct leakage must be conducted by a HERS Rater for multifamily buildings with up to three habitable stories. For other multifamily buildings in Climate Zones 2, 4, 6, and 8-16, testing only needs to be conducted and certified by the installing contractor and neither a HERS Rater nor registration with a HERS Provider is required. Entirely new or complete replacement duct systems as part of an addition or alteration in all climate zones are required to comply with these mandatory maximum leakage criteria. A duct system in an existing building is considered entirely new when:

- At least 75% of the duct material is new.
- All remaining components from the previous system are accessible and can be sealed.

11.5.4.4 Air Filtration

§160.2(b)1

Air filtration is used in forced air systems to protect the equipment from dust accumulation that could reduce the capacity or efficiency of the system. Preventing dust buildup may also prevent the system from becoming a host to biological contaminants such as mold, especially if dust is deposited on cooling coils that become wet from water condensation during comfort cooling operation. Air filter efficiencies of Minimum Efficiency Reporting Value (MERV) 6 to MERV 8 are sufficient for protection from these large airborne dust particles. Air filter efficiencies of at least MERV 13 are needed to protect occupants from exposure to the smaller airborne particles that are known to adversely affect respiratory health. These smaller particles are often referred to as PM 2.5, which refers to particulate matter of 2.5 microns or smaller. PM2.5 is produced from several sources including combustion from cooking and from exhaust from motor vehicles that enters a dwelling through ventilation openings and infiltration.

AA. Air Filter Pressure Drop

Standards §160.2(b)1D requires all systems to be designed to accommodate the clean-filter pressure drop imposed by the system air filter device(s). This applies to space-conditioning systems and to the ventilation system types described in the *Air Filter Particle Removal Efficiency Requirements – MERV 13* section. The design airflow rate and maximum allowable clean-filter pressure drop at the design airflow rate applicable to each air filter device must be determined and posted on a sticker or label by the installer inside the filter grille or near the filter rack, according to *Air Filter Particle Removal Efficiency Requirements – MERV 13* section below.

Designers of space-conditioning systems must determine the total system external static pressure losses from filters, coils, ducts, and grilles, such that the sum is not greater than the available static pressure of the air handling unit at the design airflow rate. Therefore, air filters should be sized to minimize static pressure drop across the filter during system operation. The air filter pressure drop can be reduced by increasing the amount of air filter media surface area available to the system airflow. Increased media surface area can be accomplished by adjusting one, two, or all three of the following factors:

- **Adjust the number of pleats of media per inch inside the air filter frame.** The number of pleats per inch inside the filter frame is determined by the manufacturer's filter model design and is held constant for all filter sizes of the same manufacturer's model. For example, all 3M Filtrete 1900 filters will have the same media type, the same MERV rating, and the same number of pleats of media per inch inside the filter frame regardless of whether the nominal filter size is 20" X 30" or 24" X 24", and so forth. Generally, as the number of pleats per inch is increased, the pressure drop is reduced if all other factors remain constant. The pressure drop characteristics of air filters vary widely between air filter manufacturers and between air filter models, largely because of the number of pleats per inch in the manufacturer's air filter model design. System designers and system owners cannot change the manufacturer's filter model characteristics, but they can select a superior air filter model from a manufacturer that provides greater airflow at a lower pressure drop by comparing the filter pressure drop performance shown on the air filter manufacturer's product label (see example label in Table 11).

- **Adjust the face area of the air filter and filter grille.** Face area is the nominal cross-sectional area of the air filter, perpendicular to the direction of the airflow through the filter. Face area is also the area of the filter grille opening in the ceiling or wall. The face area is determined by multiplying the length times width of the filter face (or filter grille opening). The nominal face area for a filter corresponds to the nominal face area of the filter grille in which the filter is installed. For example, a nominal 20" X 30" filter has a face area of 600 in^2 and would be installed in a nominal 20" X 30" filter grille. Generally, as the total system air filter face area increases, the pressure drop is reduced if all other factors remain constant. Total system air filter face area can be increased by specifying a larger area filter/grille or by using additional/multiple return filters/grilles, summing the face areas. The filter face area is specified by the system designer or installer.
- **Adjust the depth of the filter and filter grille.** Air filter depth is the nominal filter dimension parallel to the direction of the airflow through the filter. Nominal filter depths readily available for purchase include one, two, four, and six inches. Generally, as the system air filter depth increases, the pressure drop is reduced if all other factors remain constant. For example, increasing filter depth from one inch to two inch nominally doubles the filter media surface area without increasing the filter face area. The filter depth is specified by the system designer or installer.

BB. Air Filter Particle Removal Efficiency Requirements – MERV 13

An air filter with a particle removal efficiency equal to or greater than MERV 13 or a particle size efficiency rating equal to or greater than 50 percent in the

0.30-1.0 μm range, and it is and equal to or greater than 85 percent in the 1.0-3.0 μm range is required for the following systems:

- Mechanical space conditioning (heating or cooling) systems with a total of more than 10 ft. of duct. The total is determined by summing the lengths of all the supply and return ducts for the forced-air system.
- Mechanical supply-only ventilation systems that provide outside air to an occupiable space.
- The supply side of mechanical balanced ventilation systems, including heat recovery ventilation systems and energy recovery ventilation systems that provide outside air to an occupiable space.

Evaporative coolers are exempt from the air filtration requirements.

CC.Air Filter Requirements for Space-Conditioning Systems:

- Space conditioning systems may use any of the three following compliance approaches:
- Install a filter grille or accessible filter rack that accommodates a minimum 2-inch depth filter and install the appropriate filter.
- Install a filter grille or accessible filter rack that accommodates a minimum 1″ depth filter and install the appropriate filter. The filter/grille must be sized for a velocity of ≤ 150 ft per minute. The installed filter must be labeled to indicate the pressure drop across the filter at the design airflow rate for that return is ≤ 0.1 inch water column (w.c. [25 PA]).

Use the following method to calculate the 1" depth filter face area required. Divide the design airflow rate (ft^3/min) for the filter grille/rack by the maximum allowed face velocity 150 ft/min. This yields a value for the face area in ft^2. Since air filters are sold using nominal sizes in terms of inches, convert the face area to in^2 by multiplying the face area (ft^2) by a conversion factor of 144 in^2/ft^2. Summarizing:

Filter Nominal Face Area (in^2) = airflow (CFM) ÷ 150 x 144

- Comply with Standards Tables 160.3-A and B, which prescribe the minimum total system nominal filter face area and return duct size(s). The installed filter must be labeled to indicate the pressure drop across the filter at the design airflow rate for that return is ≤ 0.1 inch w.c. (25 PA). This option is an alternative to the §160.3(b)5L requirement for HERS-verified fan efficacy and airflow rate, but it requires instead a HERS verification of the return duct design.

DD. Air Filter Requirements for Ventilation Systems

- Filters with a depth of 1″ or greater are allowed.

- The design airflow rate, and maximum allowable clean-filter pressure drop at the design airflow rate applicable to each air filter device, must be determined by the system designer or installer and that information must be posted on a sticker by the installer inside or near the filter grille/rack according to Chapter 11.6.4.10FF.
- Ventilation systems must deliver the volume of air specified by §160.2(b)2 with filters in place.

EE. Filter Access and Filter Grille Sticker: Design Airflow and Pressure Drop

All filters used in all system types must be accessible to facilitate replacement.

- **Air filter grille sticker**. The design airflow rate and maximum allowable clean-filter pressure drop at the design airflow rate applicable to each air filter grille/rack must be determined by the designer/installer and posted on a sticker placed by the installer inside or near the filter grille/rack. The design airflow and initial resistance posted on this sticker should correspond to the conditions used in the system design calculations. This requirement applies to space conditioning systems and also to the ventilation system types described in *Air Filter Particle Removal Efficiency Requirements – MERV 13* section above.

An example of an air filter grille sticker showing the design airflow and pressure drop for the filter grille/rack is shown in Table 11-33.

- **Air filter manufacturer label.** Space-conditioning system filters are required to be labeled by the manufacturer to indicate the pressure drop across the filter at several airflow rates. For the system to comply, and to ensure adequate airflow for efficient heating and cooling equipment operation, the manufacturer's air filter label must display information that indicates the filter can meet the design airflow rate for that return grille/rack at a pressure drop ≤ the value shown on the installer's filter grille sticker. This requirement does not apply to the ventilation system types described in *Air Filter Particle Removal Efficiency Requirements – MERV 13* section above.

Table 11-33: Example of Installer's Filter Grille Sticker

Air Filter Performance Requirement	Air Filter Performance Requirement	Maintenance Instructions
Airflow Rate (CFM) Must be greater than or equal to the value shown	Initial Resistance (IWC) Must be less than or equal to the value shown	Use only replacement filters that are rated to simultaneously meet both of the performance requirements specified on this sticker:

Air Filter Performance Requirement	Air Filter Performance Requirement	Maintenance Instructions
750	0.1	Left Blank

Source: California Energy Commission

Figure 11-46: Example Manufacturer's Filter Label

MERV	(µm)	0.30-1.0	1.0-3.0	3.0-10	Airflow Rate (CFM)	615	925	1230	1540	2085*	*Max Rated Airflow
13	PSE (%)	62	87	95	Initial Resistance (IWC)	0.07	0.13	0.18	0.25	0.38	

Source: California Energy Commission

FF. Air Filter Selection

For a filter to meet the system specifications for airflow and pressure drop, it must be rated by the manufacturer to provide more than the specified airflow at less than the specified pressure drop. It is unlikely that a filter will be available that is rated to have the exact airflow and pressure drop ratings specified, so filters should be selected that are rated to have less than the specified pressure drop at the specified airflow rate. Otherwise, select filters that are rated to have greater than the specified airflow rate at the specified pressure drop. See Table 11-34 for an example of an installer's filter grille sticker that provides an air filter rating specification for minimum airflow of 750 CFM at maximum pressure drop 0.1 inch w.c.

Manufacturers of air filters may make supplementary product information available to consumers that will assist with selecting the proper replacement filters. This product information may provide more detailed information about the filter model airflow and pressure drop performance – details such as airflow and pressure drop values that are intermediate values that lie between the values shown on their product label. The information may be published in tables, graphs, or presented in software applications available on the internet or at the point of sale.

Figure 11-47 below shows a graphical representation of the initial resistance (pressure drop) and airflow rate ordered pairs given on the example air filter manufacturer's label shown in Figure 11-49 above. The graph in Figure 11-47 makes it possible to visually determine the airflow at 0.1 inch w.c. pressure drop for which the values are not shown on the manufacturer's filter label.

If there is no supplementary manufacturer information available, and it is necessary to determine the performance of a filter model at an airflow rate or pressure drop between two values shown on a manufacturer's label, linear interpolation may be used. Linear interpolation apps are readily available on the internet, and formulas for linear interpolation are shown below.

The linear interpolation method may be used to determine an unknown pressure drop corresponding to a known airflow rate by use of Equation 11-2a, or it may also be used to determine an unknown airflow rate corresponding to a known pressure drop by use of Equation 11-2b.

$p = p_1 + [(f-f_1) \div (f_2-f_1)] \times (p_2 - p_1)$ Equation 11-2a

where:

f = a known flow value between f_1 and f_2

p = the unknown pressure drop value corresponding to f.

p_1 and p_2 = known values that are less than and greater than p respectively.

f_1 and f_2 are the known values corresponding to p_1 and p_2.

$f = f_1 + [(p-p_1) \div (p_2-p_1)] \times (f_2 - f_1)$ Equation 11-2b

where:

p = a known pressure drop value between p_1 and p_2

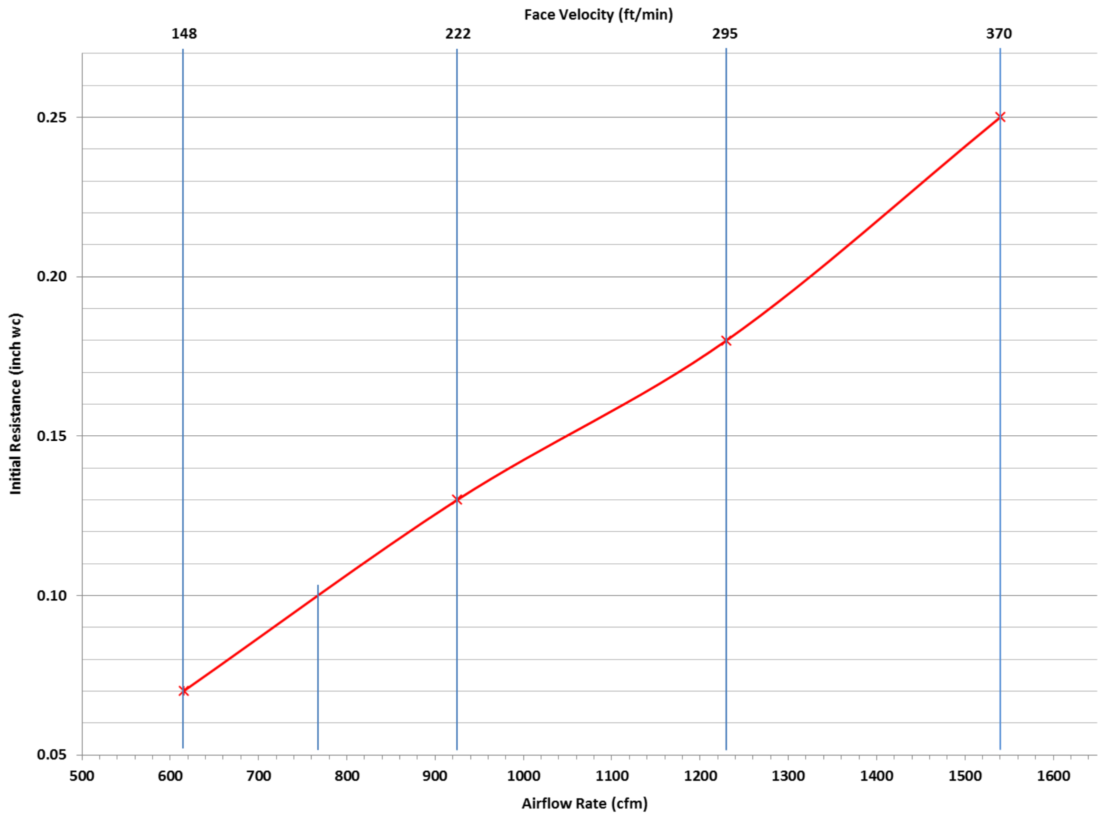
f = the unknown flow value corresponding to p.

f_1 and f_2 = known values that are less than and greater than f respectively.

p_1 and p_2 are the known values corresponding to f_1 and f_2.

See Example 11-31 for sample calculations that determine the rated airflow of the filter corresponding to a known pressure drop specification (0.1 inch w.c.).

Figure 11-47: Plot of Pressure drop vs. Airflow for a 20" X 30" X 1" Depth Air Filter



From Manufacturer Label Information

H. Preventing Bypass

Any gaps around an air filter allows air to bypass the filter. The Energy Code requires that filter racks and grilles use gaskets, sealing, or other means to close gaps around inserted filters and prevent air from bypassing the filter. Filter racks and grilles include any device that houses the air filter used to satisfy the air filtration requirements.

Example 11-31: Filter Selection Using Linear Interpolation

Question

Does the air filter label in Figure 11-49 indicate the filter would meet the airflow (750 CFM) and pressure drop (0.1 inch w.c.) requirements shown on the installer filter grille sticker in Table 11? How can I determine the filter's airflow rate at 0.1 inch w.c. for the manufacturer's filter label shown in Figure 11-49?

Answer

The filter must be rated to provide greater than 750 CFM at the specified 0.1 inch w.c. pressure drop, or equivalently: the filter must be rated to provide a pressure drop less than 0.1 inch w.c. at the specified 750 CFM.

Referring to Equation 11-2b, we calculate the unknown value "f" in CFM that corresponds to the known value "p" of 0.1 inch w.c.

Referring to Figure 4-5: p1=0.07, p2=0.13, f1=615, f2=925, and applying Equation 11-2b:

615 + [(0.1-0.07) ÷ (0.13-0.07)] x (925-615) yields 770 CFM

Therefore, since the filter is rated for greater than 750 CFM at 0.1 inch w.c., the filter complies.

Example 11-32: Filter Sizing

Question

I am installing a 1,200 CFM furnace in a new house. It has a 20" x 20" x 1” inch filter rack furnished with a 1" depth filter installed in the unit. Is this filter in compliance?

Answer

The nominal face area of the filter rack is 20" x 20" = 400 in^2, and since it is a 1” filter, the face area may not be less than 1,200 (CFM)/150x144 (in^2 / ft^2) = 1,152 in^2. Therefore, this filter installation does not comply.

Example 11-33

Question

For the same 1,200 CFM furnace, what other options do I have?

Answer

Option 1: The filter will be in compliance if it has a depth of 2 inches or more and is properly sized by the system designer such that the duct system as a whole will be capable of meeting the HERS verification for fan efficacy specified in §160.3(b)5L.

Otherwise, the required total system filter face area of 1,152 in^2 must be met using multiple remote wall or ceiling filter grilles for which the sum of the face areas is equal to or greater than 1152 in^2, and the filters must be rated for pressure drop of 0.1 inch w.c. or less at the design airflow rates of each filter grille.

Option 2: Table 160.3-A may be used for compliance. If the air conditioner is rated at 3 tons and two return ducts sized at 16” and 14” or larger are provided, the total filter/grille nominal area may be reduced to 900 in^2, or 450 in^2 per filter grille. However, the filters still must have a pressure drop of 0.1 inch or less at 600 CFM (based on filter manufacturer label data).

For any filter, the pressure drop, efficiency, and length of time the filter can remain in operation without becoming fully loaded with dust, can all be improved by using filters that are deeper than 1". As the depth of the filter is increased, the pressure drop across the filter at the same face area will be greatly reduced.

Example 11-34

Question

I am installing a ductless split system in a space that is being added on to the house. Must I use the designated MERV 13 filter?

Answer

No. The filtration requirements do not apply unless there is at least 10 ft. of duct attached to the unit.

Example 11-35

Question

My customer has allergies and wants a MERV 16 or better filter. Is this in compliance?

Answer

Yes. MERV rated filtration greater than MERV 13 meets (exceeds) the minimum particle removal efficiency requirement; thus, it may be used provided all other applicable requirements in Section 160.0(m)12 are complied with.

11.5.4.5 Forced-Air System Duct Sizing, Airflow Rate, and Fan Efficacy

§160.3(b)5L

Adequate airflow is critical for cooling equipment efficiency. Further, it is important to maintain adequate airflow without expending excessive fan power. §160.3(b)5L establishes mandatory requirements that are intended to ensure adequate cooling airflow through properly sized ducts and efficient fan motors.

There are two options allowed to ensure adequate air flow. The first option is to design and install the systems using standard design criteria and then have the airflow and fan efficacy of the system tested in the field. The second option is to size the return ducts according to Table 11-34 and Table 11-35 (as specified by EXCEPTION 1 to §160.3(b)5Lii and iv).

Both options require verification. Verification must be conducted by a HERS Rater for multifamily buildings with up to three habitable stories. For other multifamily buildings in Climate Zones 2-16, verification only needs to be conducted and certified by the installing contractor and neither a HERS Rater nor registration with a HERS Provider is required. Buildings with four or more habitable stories in Climate Zone 1 are exempt from these mandatory requirements.

A. Airflow and Watt Draw Measurement and Determination of Fan Efficacy

When using the airflow (CFM/ton) and fan efficacy (watt/CFM) method, the following criteria must be met:

- Provide airflow through the return grilles that is equal to or greater than:

  - 350 CFM per ton of nominal cooling capacity for systems that are not small-duct high-velocity systems.
  - 250 CFM per ton for small duct for high velocity systems.

Nominal cooling capacity: To determine the required airflow for compliance in CFM/ton, the nominal cooling capacity of the system in tons must be known. The nominal cooling capacity system may be obtained from the manufacturer's product literature or from listings of certified product ratings from organizations such as AHRI, but the nominal capacity is usually shown in the unit model number on the manufacturers nameplate attached to the outdoor condensing unit. A two- or three-digit section of the manufacturer's model number typically indicates the nominal capacity in thousands of BTU/hour. Given that there are 12,000 BTU/hour per ton of cooling capacity, the nameplate will display something similar to one of the following number groupings: "018" which represents 1.5 tons; "024," which represents 2 tons; "030," which represents 2.5 tons; "036," which represents 3 tons; "042," which represents 3.5 tons; "048," which represents 4 tons; or "060," which represents 5 tons.

- At the same time, the fan watt draw must be less than or equal to
  - 0.45 watts per CFM for gas furnaces, or
  - 0.58 watts per CFM for air handling units that are not gas furnaces.
  - 0.62 watts per CFM for small duct, high velocity systems.

See Table 11-36 for a summary of the requirements.

The methods for measuring the air-handling unit watt draw are described in Reference Residential Appendix RA3.3. Three acceptable apparatuses are:

- A portable watt meter.
- An analog utility revenue meter.
- A digital utility revenue meter.

Note that when measuring fan watt draw in package air conditioners or heat pumps, it is recommended to use a portable true power clamp-on meter to provide flexibility for isolating the correct fan wires. These meters may need to be high-voltage-capable.

Ducted mini-split heat pumps and air conditioners are typically exempt from the requirement to measure fan watt draw because of the difficulties with isolating the fan power and accurately measuring it. They are not exempt from the airflow measurement requirement.

There are three acceptable methods for determining compliance with the system airflow requirement. They are described in Reference Residential Appendix RA3.3 and use one of the following:

- An active or passive flow capture hood to measure the total airflow through the return grill(s)
- Flow grid device(s) at the return grill(s) or other location where all the central fan airflow passes through the flow grid
- Fan flow meter device (also known as a duct blaster) to perform the plenum pressure matching procedure

The flow grid and the fan flow meter methods both require access to static pressure measurements of the airflow exiting the cooling coil, which require use of a HSPP or PSPP (RA3.3.1.1).

The contractor must install either a hole for the placement of a static pressure probe (HSPP) or provide a permanently installed static pressure probe (PSPP) stated in Reference Residential Appendix RA3.3.

The HSPP or PSPP simplifies cooling coil airflow measurement when using devices or procedures that depend on supply plenum pressure measurements.

The California Green Code (CALGreen or Title 24, Part 11) and the California Mechanical Code require that residential duct systems be designed according to ACCA Manual D, or equivalent. If reasonable care and judgment are used while designing the duct system (both return and supply ducts), and the system is designed to reasonable parameters for airflow per ton, static pressure across the fan, and friction rate, these systems should have no problem passing the diagnostic tests.

The following design guidelines will increase the chances of the system passing the airflow and fan efficacy testing:

- Right-size the HVAC system. If a two-ton unit is enough to satisfy the cooling load, do not install a three-ton unit just to be safe. Oversizing equipment can cause comfort problems in addition to excessive energy use.
- The HVAC designer must coordinate closely with the architect and structural engineer to make sure that the ducts will fit into the dwelling unit as designed.
- Prepare a detailed mechanical plan that can be followed in the field. If deviations must occur in the field, make sure that they are coordinated with the designer and that the design is adjusted as needed.
- Follow Manual D for duct sizing:
    - Make sure that the correct duct type is used (vinyl flex, sheet metal, rigid fiberglass, or other).
    - Make sure that all equivalent lengths and pressure drops are correctly accounted for (bends, plenum start collars, t-wyes, filters, grilles, registers, and so forth.

- Select an air handler that will provide at least 400 CFM/ton at the desired static pressure of 125 to 150 Pa (0.5 to 0.6 inches w.c.).
- Design the duct system to a static pressure across the fan of no more than 150 Pa (0.6 inches w.c.).
- Consider upsizing the evaporator coil relative to the condenser to reduce the static pressure drop. This upsizing results in better airflow and slightly better capacity and efficiency. Manufacturers commonly provide performance data for such condenser coil combinations.
- Consider specifying an air handler with a high efficiency (brushless permanent magnet) fan motor.

- Install a large grill area and use a proper filter for the system.
- Locate registers and equipment to make duct runs as short as possible.
- Make all short-radius 90° bends out of rigid ducting.
- Install flex duct properly by stretching all flex duct tight and cutting off excess ducting. Ensure the duct is not kinked or compressed and is properly supported every four ft. or less using one inch strapping. Flex duct should have less than two inches of sag between supports.
- Consider using better quality supply and filter grilles. Bar-type registers have considerably better airflow performance than standard stamped-face registers. Refer to the manufacturer’s specifications and select accordingly.

B. Return Duct System Design Method

This method allows the designer to specify, and the contractor to install, a system that does not have to be tested for airflow and fan efficacy. This method can be used for systems with either one or two return grilles. Each return must not exceed 30 ft. as measured from the return plenum to the filter grille. When bends are needed, sheet metal elbows are desirable. Each return can have up to 180 degrees of bend, and flex duct can have no more than 90° of bend. To use this method, the designer and installer must provide return system sizing that meets the appropriate criteria in Energy Code Table 160.3-A and B, also shown in Table 11-34 or Table 11-35 below.

Energy Code Tables 160.3-A and B (Table 11-34 or Table 11-35) allow for only one or two returns. There may be times where three returns are necessary on a single system. Furthermore, Table 160.3-B does not allow for deviation from the two sizes specified. For example, the table requires two 14-inch return ducts for a 2.5-ton system, but specific airflow requirements and architectural constraints may dictate an 18-inch and a 12-inch. In this situation, airflow and fan efficacy diagnostic testing are required.

Historically, duct systems have been sized to fit into the dwelling unit at the expense of proper airflow. The performance of these systems, in terms of efficiency and capacity, has suffered greatly because of this practice. The dwelling unit should be designed to accommodate properly sized ducts. This requires improved coordination among the architect, structural engineer, and mechanical designer early in the process.

Tables 160.3-A and B require the use of return grilles that are sized to achieve an optimal face velocity and static pressure drop. Tables 160.3-A and B also require the return grille devices to be labeled in accordance with the requirements in §160.2(b)1A to disclose the design airflow rate of the grille and the maximum allowable clean-filter pressure drop for the air filter media, as determined by the system design or applicable standards requirements. The nominal size of the air filter grille or air filter media should be used to calculate the return filter grille gross area for determining compliance with Tables 160.3-A and B. The nominal size of the filter grille is expected to be the same as the nominal size of the air filter media that is used in the grille and is most often the information used to identify these items for purchases. For example, a nominal 20-inch x 30-inch filter grille will use nominal 20-inch x 30-inch air filter media.

Table 11-34: Return Duct Sizing for Single Return Duct Systems

System Nominal Cooling Capacity (Ton)	Minimum Return Duct Diameter (inch)	Minimum Total Return Filter Grille Gross Area (Inch^2)
1.5	16	500
2.0	18	600
2.5	20	800

Source: From Table 160.3-A of the Energy Code

Table 11-35: Return Duct Sizing for Multiple Return Duct Systems

System Nominal Cooling Capacity (Ton)	Return Duct 1 Minimum Diameter (inch)	Return Duct 2 Minimum Diameter (inch)	Minimum Total Return Filter Grille Gross Area (inch^2.)
1.5	12	10	500
2.0	14	12	600
2.5	14	14	800
3.0	16	14	900
3.5	16	16	1000
4.0	18	18	1200

5.0	20	20	1500

Source: From Table 160.3-B of the Energy Code

C. Zonally Controlled Central Forced-Air Cooling Systems

§160.3(b)5Liii

The primary purpose of zoning ducted air conditioners, heat pumps, and furnaces is to improve comfort. Increased comfort is attained by having the capacity of the HVAC system (cooling or heating delivered) follow the shift in load as it changes across the dwelling unit.

Since the most common dwelling unit is single-zoned and has only one thermostat placed near the center of the unit, temperatures in the rooms distant from that thermostat will vary, sometimes significantly. If zoning is added, the more distant rooms may be conditioned to a more comfortable temperature. This increased conditioning requires more energy. When designed correctly, zoning allows only the zones that need conditioning to be conditioned, thus potentially saving energy.

It is common for single-speed zonally controlled central forced-air cooling systems to produce lower total system airflow through the returns when fewer than all zones are calling for conditioning. The reduced airflow lowers the sensible efficiency of single-stage heating or cooling equipment. Two primary causes of lower airflow in multiple zone dampered systems are:

1. Restriction of some system supply ducts by closing zoning dampers in zones that do not need additional cooling, while other zones do need cooling.
2. Recirculation of already-cooled air from the supply plenum directly back to the return plenum without first delivering the cooled air to the conditioned space by use of a bypass duct.

To prevent the lower efficiency that results from reduced system airflow or from recirculated bypass duct airflow, single-speed compressor zonally controlled central cooling systems must demonstrate they simultaneously meet mandatory fan efficacy and airflow requirements in all zonal control modes, which is possible with a duct system design that does not restrict the system total airflow when fewer than all zones are calling for conditioning and does not use a bypass duct. §170.2(c)3v prohibits use of bypass ducts prescriptively, but bypass ducts may be used if the efficiency penalty due to the reduced airflow through the return grille is modeled as described later in this section.

Zonally controlled cooling systems with or without bypass dampers (multiple zones served by a single air handler with motorized zone dampers) usually do not meet the airflow and fan efficacy requirements when fewer than all zones are calling. The energy penalty that results from this is greater than the benefit of having zonal control; therefore, zonal control is not always a better-than-minimum condition.

Zonal control accomplished by using multiple single-zone systems is not subject to the requirements specified in §160.3(b)5Liii.

Two-speed and variable-speed compressors are considered multi-speed. Multispeed compressors allow the system capacity to vary to match reduced cooling loads more closely when fewer than all zones call for cooling. Therefore, an exception to §160.3(b)5Liii gives multispeed compressor systems special consideration when used in zoned systems, and these systems are not required to verify performance in all zonal control modes. Instead, the airflow and fan efficacy testing are required to be performed only at the highest speed when all zones call for cooling.

An exception to §160.3(b)5Liii allows single-speed compressor systems to comply with the mandatory airflow and fan efficacy requirements only at the highest fan speed and when all zones call for cooling, rather than in every zonal control mode. This is allowed if:

- The performance approach is used.
- Airflow is tested in all zonal control modes when fewer than all zones call for cooling to be no less than that specified by the software user and reported on the compliance report.
- Fan efficacy is tested in all zonal control modes to be no greater than that specified by the software user and reported on the compliance report.

In the compliance software, if the system is modeled as a zoned system with a single-speed compressor, the minimum allowable airflow drops to 150 CFM/ton. The compliance software calculates a penalty for the reduced airflow (specified by the user) during operation when fewer than all zones call for cooling. Other energy features for the building must offset this penalty. A value between 150 CMF/ton and 350 CFM/ton can lessen the penalty resulting from the minimum allowed value of 150 CFM/ton.

The energy consultant should model airflow and fan efficacy values that are reasonable and can be verified. If not, the compliance calculations will have to be revised to match the actual verified value. Energy consultants should coordinate with the HVAC designer before registering the certificate of compliance.

See Table 11-36 for a summary of the requirements.

Bypass dampers may be installed only if the certificate of compliance specifically states that the system was modeled as having a bypass damper.

Table 11-36: Central Forced-Air Cooling Systems Airflow & Fan Efficacy Requirements

Compressor & Zone Type	Mandatory Requirements for Airflow[1]	Mandatory Requirements for Fan Efficacy[1]	Performance Approach Proposed Design System Defaults	Performance Approach Standard Design System Assumptions
Single Zone Single-Speed or Multispeed (tested on highest speed only)	• ≥ 350 CFM/ton • ≥ 250 CFM/ton if a small duct high velocity (SDHV) type	• ≤ 0.45 W/CFM for gas furnaces (GF) • ≤ 0.58 W/CFM for all other air handlers • ≤ 0.62 W/CFM for SDHV type	Same as mandatory	Same as mandatory
Zonally Controlled Single Speed (tested at all zonal control modes)[2]	• ≥ 350 CFM/ton • ≥ 250 CFM/ton if a small duct high velocity (SDHV) type	• ≤ 0.45 W/CFM for gas furnaces (GF) • ≤ 0.58 W/CFM for all other air handlers • ≤ 0.62 W/CFM for SDHV type	150 CFM/ton	Same as mandatory
Zonally Controlled Multispeed (tested at all zonal control modes)	• ≥ 350 CFM/ton • ≥ 250 CFM/ton if a small duct high velocity (SDHV) type	• ≤ 0.45 W/CFM for gas furnaces (GF) • ≤ 0.58 W/CFM for all other air handlers • ≤ 0.62 W/CFM for SDHV type	350 CFM/ton	Same as mandatory

[1]Exception: Airflow and fan efficacy testing not required if return system meets Tables 160.3-A or B. However, verification that return duct installation meets Tables 160.3-A or B is required

[2] For the prescriptive approach use of a bypass duct is not allowed. For the performance approach use of a bypass duct may be specified in the compliance software input for the zoned system type.

D. Hole for Static Pressure Probe (HSPP) or Permanently Installed Static Pressure Probe (PSPP)

§160.3(b)5Li

Space-conditioning systems that use forced air ducts to cool occupiable space must have a HSPP or PSPP installed downstream from the evaporator coil. The HSPP or PSPP must be installed in the required location, in accordance with the specifications detailed in Reference Residential Appendix RA3.3. The HSPP or PSPP are required to promote system airflow measurement when using devices/procedures that depend on supply plenum pressure measurements. The HSPP or PSPP allows HERS Raters to perform the required diagnostic airflow testing in a nonintrusive manner by eliminating the necessity for the raters to drill holes in the supply plenum for placement of pressure measurement probes.

The size and placement of the HSPP/PSPP must be in accordance with RA3.3.1.1 and must be verified by a HERS Rater. If the HSPP/PSPP cannot be installed as shown in Figure RA3.3-1 because of the configuration of the system or that the location is not accessible, an alternative location may be provided that can accurately measure the average static pressure in the supply plenum. If an alternative location cannot be provided, then the HSPP/PSPP is not required to be installed. The HERS Rater will verify this for multifamily buildings up to three stories. Not installing an HSPP/PSPP will limit the airflow measurement method to either a powered flow hood or passive (traditional) flow hood.

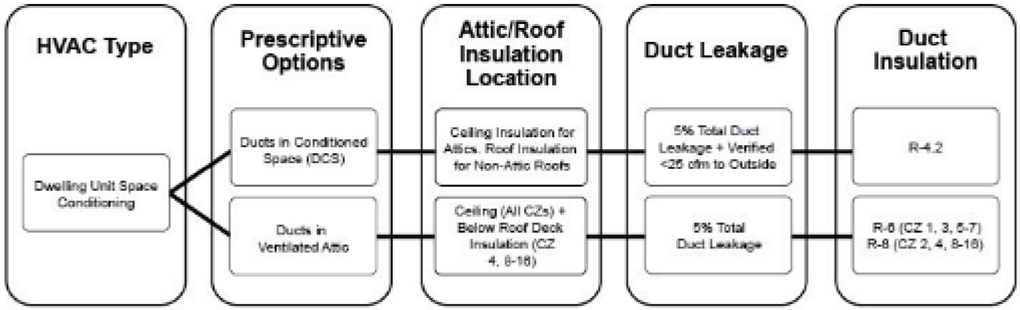
The HSPP/PSPP requirement also applies when the plenum pressure matching method or the flow grid method of airflow measurement is used by either the installer or the rater to verify airflow in an altered system. The HSPP/PSPP must be installed by the installer, not the rater.

See Chapter 11.6.4 for discussion regarding mandatory sizing/airflow requirements for ducted systems with cooling.

11.5.4.6 Dwelling Unit Prescriptive Requirements

The Energy Code is designed to offer flexibility to multifamily newly constructed building designers and builders to achieve code compliance as shown in Figure 11-48.

Figure 11-48: Duct Prescriptive Compliance Choices



Source: California Energy Commission

11.5.4.7 Duct Location

§170.2(c)3Bii

Standard multifamily construction practice in California is to place ducts and associated air handling equipment in conditioned space. Ducts are typically in a dropped soffit or in-between floors, and equipment may also be in the ceiling or an interior mechanical closet. When meeting the prescriptive requirements for the Energy Code, there are two options for where ducts and equipment can be located:

- Ducts in conditioned space (DCS) with the duct system and air handler(s) within the thermal envelope and air barrier of the building. This DCS option requires field verification to meet the prescriptive requirement. This option applies to both attic roofs and non-attic roofs.
- For buildings with attic roofs, ducts may be installed in a vented attic if Option B in Table 170.2-A is met. Option B requires a high-performance attic (HPA) design in climate zones 4 and 8-16. A HPA implements requirements that minimize temperature differences between the attic space and the conditioned air being transported through ductwork in the attic. The package consists of insulation below the roof in addition to insulation at the ceiling. These requirements and approaches to meet the requirements are explained in Chapter **Error! Reference source not found.** of this manual.

For the DCS prescriptive approach, additional requirements apply:

- Air handlers containing a combustion component should be direct-vent (sealed combustion chambers) and must not use air from any conditioned or unconditioned space as combustion air. Other types of combustion heating systems are possible if the system installer adheres to the combustion air requirements found in Chapter 7 of the California Mechanical Code.
- Duct location needs to be verified through a visual inspection per Reference Residential Appendix RA3.1.4.1.3. This must be conducted by a HERS Rater for

multifamily buildings up to three habitable stories. Otherwise, the installing contractor can certify the results.

- Duct leakage to outside needs to be confirmed by field verification and diagnostic testing in accordance with Reference Residential Appendix RA3.1.4.3.8. This must be conducted by a HERS Rater for multifamily buildings up to three habitable stories. Otherwise, the installing contractor can certify the results.

For the vented attic with HPA prescriptive approach, additional requirements apply. Refer to Chapter 3.5 of the Single-Family Compliance Manual for more information on this option.

- Ducts are insulated to a level required in Table 170.2-K.
- Ceiling and below roof deck insulation must meet the levels required in Table 170.2-A Option B. Roof deck insulation must be installed with an air space present between the roofing and the roof deck, such as is typical with standard installation of concrete or clay tile.
- Roofing products must meet the reflectance and emittance values in Table 170.2-A Option B.
- A radiant barrier is required is Climate Zones 2, 3, and 5-7 per Table 170.2-A Option B.

If a building is not able to meet all the requirements listed above, it must use the performance approach. The prescriptive options apply to dwelling units individually. Multifamily buildings with vented attics may have ductwork in the attic above the top floor units with lower floor unit ductwork in conditioned space. To comply prescriptively, the top floor units need to meet the requirement for ducts in a vented attic, which may include HPA depending on climate zone. The lower floor units need to meet all the requirements for DCS.

There are several methods of achieving the goal of DCS. For additional information, the basic information of the strategies, related benefits, challenges, and potential solutions to those challenges are described in the Single-Family Compliance Manual Chapter 4.4.2.

11.5.4.8 Duct Insulation

§170.2(c)3B

Projects meeting the prescriptive requirements for DCS need to only meet the mandatory insulation requirements of R-6. All ducts in a ventilated attic space must be insulated to a minimum installed level as specified by Table 170.2-K, which requires either R-6 or R-8 depending on the climate zone. Prescriptively, the attic must also meet the insulation requirements per Table 170.2-A Option B. Since R-6 is the mandatory minimum for ducts in unconditioned space, where R-8 is prescriptively required, this can be traded off against other features using the performance approach.

11.5.4.9 Central Fan-Integrated (CFI) Ventilation

CFI ventilation uses a central forced air heating and/or cooling system that operates regularly to pull outside air into the air distribution system and distribute air around the dwelling unit. There is a prescriptive requirement that CFI systems meet the same mandatory fan efficacy requirements for other forced air cooling systems. This requires no greater than 0.45 W/CFM for gas furnaces and 0.58 W/CFM for all other air handler including heat pumps. This can be traded-off using the performance approach. Verification must be conducted by a HERS Rater for multifamily buildings with up to three habitable stories. For other multifamily buildings, verification only needs to be conducted and certified by the installing contractor, and neither a HERS Rater nor registration with a HERS Provider is required.

11.5.4.10 Dwelling Unit Performance Approach

The Energy Code provide credit for several compliance options related to duct design and construction.

11.5.4.11 System Airflow and Fan Efficacy

Performance compliance credits are available for demonstrating the installation of a high-efficiency system with a lower fan wattage and/or higher airflow than the mandatory requirements. Compliance with these credits can be achieved by installing a well-designed duct system and can be assisted by a high-efficiency fan. There are two possible performance compliance credits:

- The performance approach allows the user's proposed fan efficacy to be entered and credit earned if it is lower than the default mandatory values. To obtain this credit for a system with cooling, the system airflow must meet the mandatory requirement of at least 350 CFM/ton of nominal cooling capacity.
- The performance approach allows the user's proposed system airflow to be entered and credit earned if it is higher than the default of 350 CFM/ton of nominal cooling capacity. To obtain this credit, the fan efficacy must meet the mandatory requirements listed above.

The performance approach allows the user's proposed airflow and fan efficacy to be entered into the program, and credit will be earned if the airflow is greater than the minimum required, and fan efficacy is lower than the default. After installation, the contractor must test the actual airflow and fan efficacy of each system using the procedure in *Reference Residential Appendix* RA3.3 and show that it is equal or less than what was proposed in the compliance software analysis.

For multifamily buildings up to three habitable stories the fan efficacy and airflow must be verified by a HERS Rater.

11.5.4.12 Duct Location

For multifamily buildings up to three habitable stories, there are three ways to achieve credit for favorable duct location when using the performance approach and the building has an attic.

- Credit is available if no more than 12 linear ft. of duct are outside the conditioned space. This total must include the air handler and plenum lengths. This credit results in a reduction of duct surface area in the computer software. This option requires certification by the installer and field verification by a HERS Rater.
- The second alternative applies when 100% of the ducts are in conditioned space. This credit results in eliminating the conduction losses associated with the return and supply ducts; however, leakage rates still apply. This option requires field verification of the duct system by means of a visual inspection by a HERS Rater.
- Additional credit is available when ducts are in conditioned space and a HERS Rater verifies that duct leakage to outside does not exceed 25 CFM.

There may also be compliance credit for the distribution system for choosing a ductless heating or cooling system. However, many of these systems do not perform as well as the baseline system, which can result in an overall penalty.

For buildings with no attic, the standard design assumes ducts inside the conditioned space with duct leakage verified to not exceed 25 CFM. No additional credit is available within the software for duct location.

There is no duct location compliance credit for multifamily buildings four or more habitable stories, because the software does not evaluate distribution systems.

11.5.4.13 Duct Insulation

For multifamily buildings up to three habitable stories, performance credit is available for ducts in unconditioned space if all the ducts are insulated to a level higher than required by the prescriptive package. If ducts with multiple R-values are installed, the lowest duct R-value must be used for the entire duct system. However, the air handler, plenum, connectors, and boots must be insulated to the mandatory minimum R-value.

As an alternative when there is a mix of duct insulation R-values, credit is available through the method described in the next section.

There is no duct insulation compliance credit for multifamily buildings four or more stories, because the software does not evaluate distribution systems.

11.5.4.14 Verified Duct Design: Duct Location, Surface Area, and R-value

For multifamily buildings up to three habitable stories when all or a portion of ducts are in unconditioned space, this compliance option allows the designer to take credit for a high-efficiency duct design that incorporates duct system features that may not meet the criteria for the duct location and/or insulation compliance options described above. This method requires that the designer enter the design characteristics of all ducts that are not within the conditioned space. The information required for the input to the compliance software includes the length, diameter, insulation R-value, and location of all ducts. This method will result in a credit if the proposed duct system is better than the standard design.

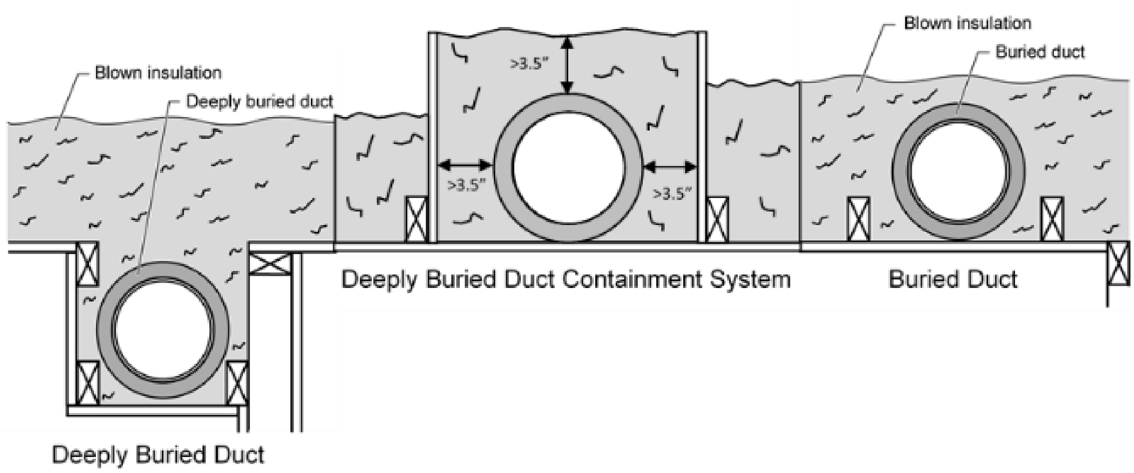
To claim this credit, the duct system design must be documented on plans that are submitted to the enforcement agency and posted at the construction site for use by the installers, the enforcement agency field inspector, and the HERS Rater. The duct system must be installed in accordance with the approved duct system plans, and the duct system installation must be certified by the installer on the certificate of installation form and verified by a HERS Rater on the certificate of verification form. Details of this compliance option are described in the Nonr*esidential ACM Reference Manual*, and verification procedures are described in RA3.1 of the Reference Residential Appendix.

11.5.4.15 Buried and Deeply Buried Ducts

For multifamily buildings up to three habitable stories, this compliance option allows credit for the special case of ducts that are buried by blown attic insulation. For ducts that are within 3.5 inches of the ceiling, the effective R-value is calculated based on the duct size and R-value, depth of ceiling insulation, and type of blown insulation (fiberglass or cellulose) as shown in Tables 16, 17, and 18 in the Residential ACM Reference Manual. The user-entered duct system can be any combination of unburied, buried, and deeply buried duct runs. The software will determine the overall duct system effective R-value by weight averaging the user entered duct system.

Ducts must have a minimum insulation level prior to burial, R-6 for new ducts and R-4.2 for existing. Deeply buried ducts meet the requirements for buried ducts on the Ceiling and ducts are completely covered by at least 3.5 inches of attic insulation. Deeply buried ducts must be enclosed in a lowered portion of the ceiling or buried by use of a durable containment system (e.g., gypsum board, plywood, etc.), or buried under a uniform level of insulation that achieves the 3.5-inch burial level.

Figure 11-49: Buried Ducts on Ceiling and Deeply Buried Ducts



Source: California Energy Commission

Deeply buried containment systems must be installed such that the walls of the system are at least 7 inches wider than the duct diameter (3.5-inch clearance on each side of duct) extend at least 3.5 inches above the duct outer jacket, and the containment area surrounding the duct must be completely filled with blown insulation.

In addition to the above requirements, the attic area containing the buried or deeply buried ducts must have insulation with uniform depth (not mounded over the duct), level ceiling, and at least six inches of space between the duct outer jacket and the roof sheathing. Insulation raised by a containment system is an exception to the uniform depth requirement.

To take credit for buried ducts, the system must meet the verified duct system design criteria described above and meet the requirements for QII described in Reference Appendices RA3.5.

11.5.5 Common Use Area Space Conditioning Systems Requirements

This section provides an overview of the Energy Code requirements for space conditioning systems serving common use areas of the building, such as community rooms, corridors, fitness areas, and common laundry rooms. Since there are similar requirements for space conditioning systems serving common use area and systems serving nonresidential occupancies, more detailed discussion of the applicable requirements can be found in Chapter 4.

Requirements for systems serving nonresidential occupancies in mixed occupancy buildings are in §120, §130, §140 and §141 of the Energy Code.

11.5.5.1 Common Use Area Mandatory Requirements

§110.1, §110.2, §110.5, §160.2(c)1, §160.3(a)2, §160.3(c)1, §160.3(c)2 A through §160.3(c)2.H, §160.3(d)1 and §160.3(d)3

Applicable mandatory requirements for common use area space conditioning systems, as described in Chapter 4 include:

- Space conditioning equipment certification and equipment efficiency
- Restrictions on pilot lights for natural gas appliances and equipment
- Space conditioning system air filtration
- Space conditioning system controls
- Fluid distribution system: Pipe insulation
- Fluid distribution systems - Requirements for Air Distribution System, Ducts, and Plenum
- Mechanical acceptance testing

Residential equipment used in common use areas needs to meet requirements outlined in Chapter 11.6.3.1.

11.5.5.2 Common Use Area Prescriptive Requirements

§170.2(c) 1, §170.2(c) 2, and §170.2(c) 4

Applicable Prescriptive requirements for common use area space conditioning systems are covered in Chapter 4 and include:

- Space conditioning system sizing and equipment selection
- Space conditioning system calculations
- Space conditioning system requirement

11.5.5.3 Common Use Area Performance Approach

§170.1

Refer to Chapter 4.9 for applicable performance approach requirements for common use area space conditioning systems.

11.5.6 Alternative Systems

Alternative system types can comply through the performance approach. This section describes some common alternative systems used in dwelling units and the associated code requirements. See Chapter 4 for more about systems serving common use areas and central systems.

11.5.6.1 Variable Capacity Heat Pumps

Several manufacturers offer mini-split or multi-split heat pump equipment that may or may not use air distribution ducts to heat or cool spaces. These systems provide advanced controls and multispeed compressors for optimizing performance through a wide range of conditioning loads.

These systems are generally required to be modeled as minimally efficient systems. A variable capacity heat pump (VCHP) compliance option is available to provide credit for systems meeting the eligibility requirements published in the Residential Appendices RA3.4.4.3. The credit can be applied through a CEC-approved modeling software by selecting the VCHP compliance option for the HVAC system type. The certificate of compliance will indicate when a space conditioning system requires verification of the VCHP compliance option eligibility requirements. A system that does not meet the eligibility requirements upon verification will not be eligible to claim the VCHP performance compliance credit for the specified space conditioning system.

Compliance with the mandatory duct system sealing and leakage and fan airflow rate and fan efficacy testing are not required for systems that use this VCHP performance compliance option. However, there are requirements to verify that VCHP system indoor unit ducts are located entirely in conditioned space that are specified as eligibility requirements for this compliance option. There are also requirements for verification of minimum airflow rates for VCHP system indoor units that are specified as eligibility requirements for this compliance option.

Additional verification requirements apply depending on the system type and credit taken, including:

- Low-static certification for ducted systems
- Non-continuous indoor unit fan operation
- Refrigerant charge verification
- Ducts located entirely in conditioned space
- Indoor units located entirely in conditioned space
- Supply to all habitable spaces
- Wall-mounted thermostat
- Space-conditioning system airflow
- Air filter sizing
- Air filter pressure drop rating

11.5.6.2 Hydronic Heating Systems

Hydronic heating is the use of hot water to distribute heat. A hydronic heating system consists of a heat source, which may be a gas boiler, gas or heat pump water heater, and a distribution system. There are three main types of hydronic distribution systems, and they may be used individually or in combination: baseboard convectors or radiators, air handlers, and radiant panel systems. Radiant panel surfaces can include floors, walls, and/or ceilings. Air handlers and radiant panels may be used for heating and cooling. Hot water air handlers may also be equipped with DX coils for cooling. The three distribution options are illustrated in Figure 11-50. Ducting is used only with air handlers.

If the hydronic system serves both dwelling units and common use areas or nonresidential spaces, applicable requirements for nonresidential space conditioning system must be met too.

11.5.6.3 Hydronic Heating Systems Mandatory Requirements

For hydronic heating systems without ducts, the mandatory requirements cover pipe insulation, tank insulation, and boiler efficiency. For fan coils with ducted air distribution, the mandatory air distribution requirements also apply. For combined hydronic systems, as described below, mandatory water heating requirements also apply to the water heating portion of the system.

E. Pipe and Tank Insulation

§160.3(b)6 and 160.3(c)1 Pipe Insulation

The typical residential hydronic heating system operating between 105° and 140° F must have at least 1 inch (25 mm) of insulation on pipes less than 1 inch in diameter and 1.5 inch (38 mm) of insulation on pipes 1 inch or more in diameter. Systems operating between 141° and 200° F must have at least 1.5 inches of insulation on pipes less than 1.5 inches in diameter. For other temperatures and pipe insulation characteristics, see **Error! Reference source not found.**.

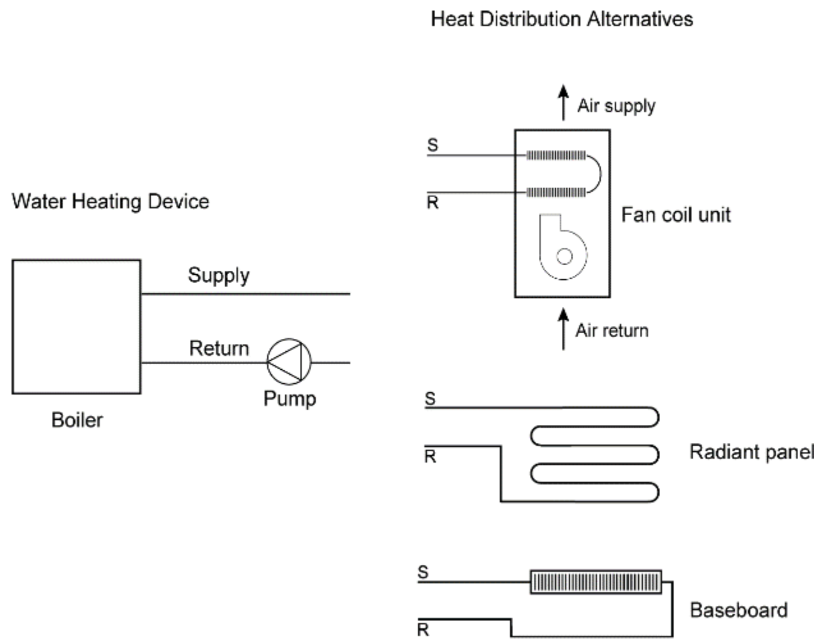
There are a few exceptions where insulation is not required:

- Sections of pipes where they penetrate framing members
- Pipes that provide the heat exchange surface for radiant heating and/or cooling
- Piping in the attic that is covered by at least 4 inches (100 mm) of blown insulation on top
- Piping installed within walls if all the requirements for QII are met (see Chapter 3 Building Envelope Requirements).

If the system includes an unfired hot water storage tank, then the tank must be either wrapped with R-12 insulation or insulated internally to at least R-16.

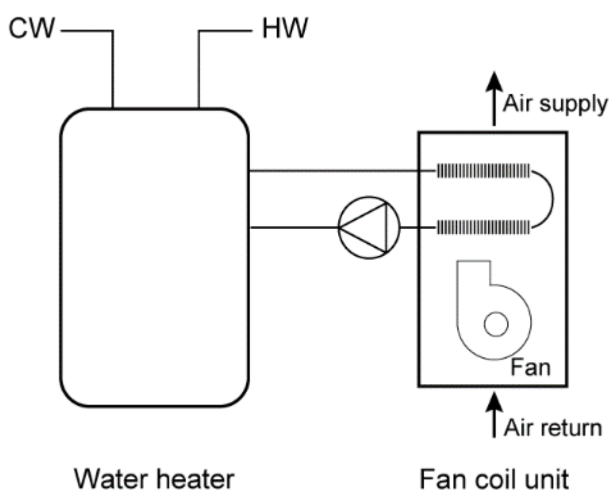
Piping used to deliver chilled water to panels or air handlers should be continuously insulated with closed-cell foam to prevent condensation damage.

Figure 11-50: Hydronic Heating System Components



Source: Richard Heath & Associates/Pacific Gas and Electric Company

Figure 11-51: Combined Hydronic System with Water Heater as Heat Source



Source: Richard Heath & Associates/Pacific Gas and Electric Company

For pipes in hydronic heating systems that operate at pressure greater than 15 psi, the requirements of §160.3(c)1apply. These are the same requirements that apply to nonresidential piping systems per §120.3.

F. Equipment Efficiency

Equipment for residential space heating must meet the minimum efficiency set by the Energy Code. Electric resistance water heaters are not allowed for use in dedicated space heating systems. Therefore, some water heaters may be used for space heating only if used as part of a combined hydronic system, as described below. In that case, the mandatory water heater requirements apply.

There are no minimum efficiency requirements for heat pumps that produce hot or chilled water, but compliance calculations must use ratings listed in the CEC's Title 20 appliance database under the category "Central Heat Pumps" and appliance type "Heat Pump Water Heating Packages."

https:/cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx

Thermostat requirements also apply to hydronic systems, as described in Chapter 4.5.1.

F. Hydronic Heating Systems Prescriptive Requirements

There are no specific prescriptive requirements that apply to hydronic systems. However, if the system has a fan coil with ducted air distribution, the relevant prescriptive requirements apply, including duct insulation and duct sealing.

G. Hydronic Heating Systems Performance Approach

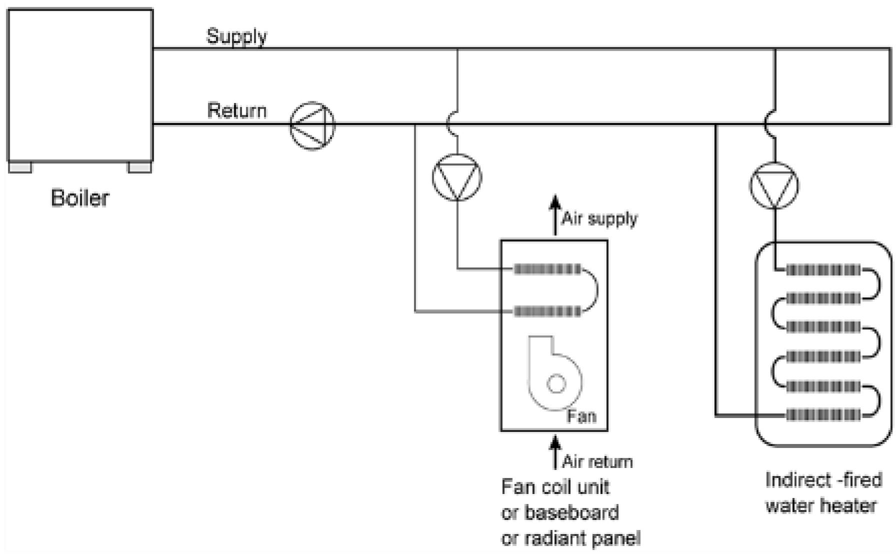
Credit for choosing a hydronic heating system is possible using the performance approach. The standard design is assumed to use air distribution system. Therefore, hydronic systems without ducts can take credit for avoiding duct leakage penalties. In addition, minimizing the amount of pipe outside conditioned space will provide some savings. Hydronic heating and cooling compliance calculations are described in the Residential ACM Manual.

If the proposed hydronic system includes ducted air distribution, then the associated compliance options described earlier in this chapter may apply, such as improved airflow (if there is air conditioning) and supply duct location.

A combined hydronic system is a compliance option using the performance method. Combined hydronic heating refers to the use of a single water heating device as the heat source for space and domestic hot water heating.

Combined hydronic systems may use either a boiler (as in the figure below) or a water heater as a heat source. The boiler heats domestic water by circulating hot water through a heat exchanger in an indirect-fired water heater. The water heater provides domestic hot water as usual.

Figure 11-52: Combined Hydronic System with Boiler and Indirect Fired Water Heater



Source: Richard Heath & Associates/Pacific Gas and Electric Company

Space heating is accomplished by circulating water from the boiler or water heater through the space heating delivery system. Sometimes a heat exchanger is used to isolate potable water from the water circulated through the delivery system. Some water heaters have built-in heat exchangers for this purpose.

For compliance calculations, the water heating function of a combined hydronic system is analyzed for water heating performance as if the space heating function were separate. For the space heating function, an effective AFUE or HSPF rating is calculated. These calculations are performed automatically by the compliance software.

11.5.6.4 Air-to-Water Heat Pumps

Air-to-water heat pumps (AWHPs) provide space heating and cooling by conditioning water at the outdoor unit and circulating it to indoor delivery systems (e.g., fan coils, radiant floors, radiant ceiling panels). Some AWHPs can also provide domestic water heating capability. Title 20 requires AWHPs to be listed, but there are currently no minimum efficiency requirements. The compliance software treats fixed compressor speed AWHPs as equivalent to the prescriptive standard air source heat pump and provides a 2% heating and 8% cooling energy reduction for variable speed AWHPs, relative to the prescriptive standard air source heat pump. Current Title 20 listings for AWHPs can be found at the following link with Category "Central Heat Pumps" and Appliance "Heat Pump Water Heating Packages" selected.

www.cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx

11.5.6.5 Radiant System

§110.8(g) and Table 110.8-A

Radiant slab-on-grade floor systems, using either hydronic tubing or electric cable, must meet mandatory insulation requirements. Radiant floors may take one of several forms. Tubing or electric elements for radiant floor systems may be:

- Embedded in a concrete floor slab.
- Installed over the top of a wood subfloor and covered with a concrete topping.
- Installed over the top of a wood subfloor in between wood furring strips.
- Installed on the underside surface of a wood subfloor

In the latter two types of installations, aluminum fins are typically installed to spread the heat evenly over the floor surface and reduce the temperature of the water as required. All hydronic systems use one or more pumps to circulate hot water. Pumps are controlled directly or indirectly by thermostats or by special outdoor reset controls.

When concrete slab-on-grade is heated by radiant tubing or cables, one of the insulation methods listed in the Energy Code Table 110.8-A must be complied with to prevent excessive heat loss from the slab edge. Chapter 3.2.8.1 provides more details about the heated slab floor insulation requirements.

Example 11-36

Question

My client wants a dedicated hydronic-heating system (space heating only), but a few things are unclear: (1) What piping insulation is required? (2) Can I use any compliance approach? (3) Do I have to insulate the slab with slab edge insulation? (4) What special documentation must be submitted for this system type?

Answer

(1) The supply lines not installed within a concrete radiant floor must be insulated in accordance with §160.3(c)1D— Systems operating between 105° and 140° F must have at least 1 inch of insulation on pipes less than 1 inch in diameter, and 1.5 inches of insulation on pipes between 1 inch and less than 1.5 inches in diameter. Systems operating between 141° and 200° F must have at least 1.5 inches of insulation on pipes less than 1.5 inches in diameter.

(2) You can use any compliance approach, but the boiler must meet the mandatory efficiency 80 percent AFUE.

(3) The slab edge insulation shown in ***Error! Reference source not found.*** is required only when the distribution system is a slab-on-grade radiant floor system (pipes in the slab). When this is the case, the insulation values shown are mandatory requirements (no modeling or credit).

(4) No special documentation is required.

11.5.6.6 Evaporatively Cooled Condensers

Evaporatively cooled condenser air conditioners are a type of air-conditioning system that can provide significant space-cooling savings, especially in hot, dry climates. The equipment minimal efficiencies are determined according to federal test procedures. The efficiencies of these air conditioners are reported in terms of energy efficiency rating (EER).

If credit is taken for a high EER, field verification by a HERS Rater is required. Other HERS verifications are also required, including duct sealing, airflow, fan efficacy, and refrigerant charge or FID.

Besides the HERS verification, there are additional special requirements for evaporatively cooled condensing air conditioners. These include that the manufacturer provide certification that water use is limited to no more than 0.15 gallon per minute per ton of capacity and that the supply line be no larger than ¼-inch in diameter. For a listing of all the requirements for evaporatively cooled condensing air conditioners, see the certificate of installation form.

11.5.7 Additions and Alterations

§180.2,

New or altered mechanical systems serving alterations or additions for dwelling units or common use areas must meet all applicable mandatory requirements and comply with either the prescriptive or performance approach. If a building does not meet all applicable prescriptive requirements, then the performance method using an approved compliance software is the alternative.

All HVAC systems serving additions generally are required to meet the newly constructed building prescriptive requirements, with few exceptions. Table 11-37 summarizes the requirements.

Table 11-37: HVAC Requirements for Prescriptive Additions

Component	Additions
New or replaced space conditioning system(s)	All prescriptive requirements per §170.2 except the system may be a heat pump or gas heating system
Use existing space conditioning system(s)	No requirements for the heating/cooling equipment except that heating system must have adequate capacity
New duct system(s)	All prescriptive requirements per §170.2
Extend existing duct system(s)	Duct sealing and duct insulation per §180.2(b)2Aii

Source: California Energy Commission

If the heating and cooling system is unchanged as part of an addition or alteration, compliance for the HVAC system is not necessary. However, changing, altering, or replacing any component of a system triggers prescriptive requirements for that component. If the extended ducts are serving dwelling units, the combined new and existing duct system must meet the requirement to seal the ducts and verify that duct leakage is no greater than 15% of system airflow. If 15% leakage or lower cannot be attained, there are alternatives, including sealing all accessible leaks and confirming by a visual inspection.

When the HVAC system is entirely new or a complete replacement, then additional mandatory and prescriptive requirements apply.

The Energy Code make a distinction between two HVAC changeout situations:

- Entirely new or complete replacement space conditioning systems.
- Altered space conditioning systems.

11.5.7.1 Entirely New or Complete Replacement Space Conditioning Systems Serving Dwelling Units

§180.2(b)2Ai and Table 180.2-C

An entirely new or complete replacement must meet all applicable mandatory and prescriptive requirements as described below.

- §160.2(b)1: Air filtration requirements.
- §160.3(a)1: Setback thermostats or controlled by EMCS.
- §160.3(b)1-2: Cooling and heating load calculations.
- §160.3(b)3: Outdoor condensing unit requirements.
- §160.3(b)4: Heating furnace temperature rise requirements.
- §160.3(b)5A-J: Duct insulation, labeling, & damper requirements.
- §160.3(b)5L: Static pressure probe, airflow, and fan efficacy requirements (or alternative return duct sizing as per Table 160.3-A and B). Multifamily buildings in Climate Zone 1 with four or more habitable stories are exempt from this requirement.
- §160.3(b)6: Pipe insulation.
- §170.2(c)3A: Prescriptive heating system type: the new or complete replacement space-conditioning system may be a heat pump or gas heating system.
- §170.2(c)3Bi: Prescriptive refrigerant charge verification.
- §170.2(c)3Biii: Prescriptive central fan integrated ventilation system airflow and fan efficacy.
- Table 180.2-C: Prescriptive duct insulation.

A system installed in an existing dwelling unit as part of an alteration must be considered entirely new when both of the following conditions are met:

- The air handler and all the system heating/cooling equipment (e.g., outdoor condensing unit and indoor cooling or heating coil for split systems; or complete replacement of a package unit), are new.
- The duct system is entirely new (including systems with less than 40 ft. in length).

  An entirely new duct system may be part of an entirely new space conditioning system, or it may be connected to an existing space conditioning system. Duct systems are classified as entirely new when:

- At least 75% of the duct material is new. Up to 25% may be composed of reused parts from the existing duct system.
- All remaining components from the previous system are accessible and can be sealed.

  Completely new or replacement duct systems in dwelling units must meet the 12% (total leakage protocol) or 6% (leakage to outside protocol) criteria used for newly constructed systems. A new duct system may be connected to an existing air handler, which typically leaks substantially more than new equipment. If the 12% leakage rate criteria cannot be met, a smoke test should be performed to verify that excess leakage is not from other accessible portions of the duct system. The protocol for the smoke test for accessible-duct sealing is given in RA3.1.4.3.7.

  Verification of duct leakage must be conducted by a HERS Rater for multifamily buildings with up to three habitable stories. For other multifamily buildings, testing only needs to be conducted and certified by the installing contractor and neither a HERS Rater nor registration with a HERS Provider is required.

  In addition, entirely new ducts systems must meet the following mandatory requirements:

- §160.2(b)1: Air filtration requirements.
- §160.3(b)5L: Static pressure probe, airflow, and fan efficacy requirements (or alternative return duct sizing as per Table 160.3-A and B). Multifamily buildings in Climate Zone 1 with four or more habitable stories are exempt from this requirement.

  When an entirely new duct system and the furnace or air handler it is connected to are in a vented attic the following prescriptive requirements also must be met.

- §180.2(b)1Bi: Attic insulation and air sealing requirements.

  Altered duct systems that are not entirely new or complete replacements are treated as an extension of an existing system.

11.5.7.2 Altered Space Conditioning Systems Serving Dwelling Units

11.5.7.3 New and Altered Duct System – Insulation

When more than 25 linear ft. of new ducts are installed in an unconditioned space, the new ducts must be insulated to a minimum R-value as described in Table 11-38. When

25 ft. or less of ducts are installed in an unconditioned space, they must be insulated to the minimum mandatory insulation level of R-6 in all climate zones.

Table 11-38: Duct Minimum R-Value

Climate Zone	3, 5-7	1-2, 4, 8-10, 12-13
Duct R-value	R-6	R-8

Source: California Energy Commission

When new ducts are installed in conditioned space, the ducts must be insulated to the minimum mandatory insulation level of R-6 unless an exception or alternative mandatory minimum applies. For multifamily buildings four habitable or more stories, this can be confirmed by visual verification of the enforcement agency. For multifamily buildings up to three habitable stories, the entire duct system must be tested and confirmed to be in conditioned space by a HERS Rater per RA3.1.4.3.8.

H. Altered System Duct Sealing

In all climate zones altered existing duct systems must be sealed and tested. An existing duct system is considered altered under any of the following conditions:

- An outdoor condensing unit of a split system air conditioner or heat pump is installed or replaced.
- A packaged system is completely replaced.
- A cooling or heating coil is installed or replaced.
- An air handler is installed or replaced.
- More than 25 ft. of new or replacement ducts are installed.
- The ducts are extended to serve an addition, regardless of the length of duct.

If a dwelling unit has more than one duct system, only the altered ducts or ducts connected to the altered equipment need to be sealed and verified.

There are three options for showing compliance for altered existing duct systems listed below. Compliance must at least be attempted with one of the first two options (15% total leakage or 10% leakage to outside); then the third option (sealing all accessible leaks) any of the other options can be used.

- Total leakage is less than 15% of nominal system fan airflow (RA3.1.4.3.1).
- Leakage to the outside is less than 10% of system fan airflow (RA3.1.4.3.4).
- If the first two option leakage targets cannot be met, then compliance can be achieved by sealing all accessible leaks and conducting a smoke test (RA3.1.4.3.7).

For multifamily buildings with up to three habitable stories, HERS verification is required for all options listed above. For Options 1, and 2, verification can be accomplished through sampling. For Option 3, sampling is not allowed; a certified HERS Rater must do the visual inspection and the smoke test on every house. For other multifamily buildings, testing only needs to be conducted and certified by the installing contractor, and neither a HERS Rater nor registration with a HERS Provider is required.

Some judgment is required in determining if ducts are accessible. The local code enforcement agency will have the final say when it is not immediately obvious.

There are a few cases where duct sealing and duct leakage verification are not required. These exceptions include:

- Ducts that have already been sealed, tested, and certified by a HERS Rater. This does not apply if the sealing requirements are triggered by the installation or new or replacement ducts (duct extension).
- Duct systems with less than 40 ft. of duct. This does not apply if the sealing requirements are triggered by the installation or new or replacement ducts (duct extension).
- Duct systems that are insulated or sealed with asbestos.

11.5.7.4 Altered System Refrigerant Charge Verification and Airflow

In Climate Zones 2 and 8 through 15, when a refrigerant-containing component of an air conditioner or heat pump is replaced or installed in an existing building, any system that does not have an FID installed must have refrigerant charge field tested in accordance with all applicable procedures specified in RA3.2.2 or RA1.

When refrigerant charge verification is required for compliance, the system must also comply with the minimum airflow of 300 CFM/ton according to the procedures specified in RA3.3.

Entirely new or complete replacement space-conditioning systems must meet the minimum 350 CFM/ton airflow rate compliance criterion or the duct design alternative along with the other prescriptive and mandatory requirements described above.

Verification of refrigerant charge and airflow must be conducted by a HERS Rater for multifamily buildings with up to three habitable stories. For other multifamily buildings, testing only needs to be conducted and certified by the installing contractor and neither a HERS Rater nor registration with a HERS Provider is required.

G. Thermostats

When an existing system has a refrigerant containing component added or replaced, the thermostat must be upgraded to a setback type that meets §110.2(c)

11.5.7.5 Heating System Replacements

Prescriptive compliance requires new heating systems be limited to a heat pump or a gas or propane system. Altered systems must not use electric resistance as the primary heat source unless the existing space heating system is electric resistance and one of the following conditions are met:

- Non-ducted electric resistance systems.
- Ducted electric resistance systems only when a ducted space cooling system is not being replaced or installed as part of the alteration.
- Any electric resistance systems in Climate Zones 6, 7, 8 or 15.

11.5.7.6 Entirely New or Complete Replacement Space Conditioning Systems Serving Common Use Area

§180.2(b)2Bi and Table 180.2-D

An entirely new or complete replacement must meet all applicable mandatory and prescriptive requirements as described below.

- §170.2(c)1: Space conditioning system sizing and equipment selection
- §170.2(c)2: Space conditioning system calculations
- §170.2(c)4: Space conditioning system requirement

Each new or replacement fan system must meet the fan power budget requirement specified in Table 180.2-D.

11.5.7.7 Altered Air Duct Systems Serving Common Use Area

§180.2(b)2Bii

Since there are similar requirements for altered air distribution systems serving common use area and systems serving nonresidential occupancies, more detailed discussion of the applicable requirements can be found in Chapter 4.9.1.1.1.10.

11.5.7.8 Altered Space Conditioning Systems Serving Common Use Area

§180.2(b)2Biii

Since there are similar requirements for altered space conditioning systems serving common use area and systems serving nonresidential occupancies, more detailed discussion of the applicable requirements can be found in Chapter 4.9.1.1.1.11.

11.5.8 Compliance and Enforcement

This section describes compliance documentation and field verification requirements related to heating and cooling systems.

11.5.8.1 Design-Phase Documentation

The following are heating and cooling system features that will be listed on the certificate of compliance if they exist in the proposed design:

- Information summarizing requirements for field verification and diagnostic testing is presented in Table RA2-1 of the Reference Residential Appendix RA2. The field verification and diagnostic testing protocols that must be followed to qualify for compliance credit are described in RA3 of the Reference Residential Appendix.

- Registration of the certificate of compliance with an approved HERS Provider is required for buildings up to three stories. The building owner or the person responsible for the design must submit the Certificate of Compliance to the HERS Provider Data Registry for retention according to the procedures described in §10-103 and Reference Residential Appendix RA2. Registration ensures that the project follows the appropriate verification process, provides tracking, and provides electronic access to the documentation.

11.5.8.2 Construction-Phase Documentation

During construction, the general contractor or specialty subcontractors must complete all applicable certificate of installation documents for the building design special features specified on the certificate of compliance.

Like the certificate of compliance, registration of the certificate of installation is required except for multifamily buildings four or more stories. For all other buildings, the licensed contractor responsible for the installation must submit the certificate of installation information that applies to the installation to a HERS Provider Data registry using procedures described in §10-103 and Reference Residential Appendix RA2. Certificate of installation documents corresponding to the list of special features requiring HERS Rater verification in Chapter above are required. For buildings four or more stories, the licensed contractor responsible for the installation must complete and submit the certificate of installation to the building department or authority having jurisdiction.

11.5.8.3 Field Verification and Diagnostic Testing

For buildings for which the certificate of compliance requires HERS or ATT field verification for compliance with the Energy Code, a HERS Rater or ATT must visit the site to perform field verification and diagnostic testing to complete the applicable heating and cooling system certificates of verification. Certificate of verification documents corresponding to the list of special features requiring HERS Rater or ATT verification in Chapter above are required.

Field verification for nonmandatory features is necessary only when performance credit is taken for the feature. Some field verifications are mandatory requirements and will occur in all dwelling units unless they are exempt from the requirement.

Like the certificate of compliance and certificate of installation, registration of the certificate of verification is required. The HERS Rater or ATT must submit the field verification and diagnostic testing information to the HERS Provider Data Registry as described in Chapter 2. For additional details describing HERS verification and the registration procedure, refer to Reference Residential Appendix RA2.

A. Requirements for HERS Field Verification and Diagnostic Testing

Special features requiring HERS Rater verification for multifamily buildings with up to three habitable stories:

- Duct sealing
- Verified duct design: for reduced duct surface area or buried ducts
- Low-leakage ducts in conditioned space
- Low-leakage air handlers
- Verification of return duct design
- Verification of bypass duct prohibition
- Refrigerant charge verification
- Installation of an FID
- Verified system airflow
- Air handler fan watt draw
- High energy efficiency ratio
- High SEER
- High heating seasonal performance factor
- Heat pump - rated heating capacity

The requirements in Table 11-39: require additional verification. For all multifamily buildings, testing must be conducted and certified by the installing contractor. For multifamily buildings up to three habitable stories, the contractor results must be verified by a HERS Rater and all applicable certificates of compliance, installation, and verification must be registered with an approved HERS Provider. For multifamily buildings four or more habitable stories neither a HERS Rater nor registration with a HERS Provider is required. Verification, testing, and sampling procedures should follow Chapter **Error! Reference source not found.**.

Table 11-39: Air Distribution System Verification Requirements

Feature	Mandatory	Prescriptive	Performance Credit
Duct sealing	X		X
Duct location in conditioned space	X	X (If complying with §170.2(c)Biib)	X
Low-leakage ducts in conditioned space	X	X (If complying with §170.2(c)Biib)	X
Cooling coil airflow	X		X
Air handler fan watt draw	X		X
Return duct system design	X		
Verification of bypass duct prohibition		X	
Verified duct design (reduced duct surface area / buried ducts)			X
Low-leakage air handlers			X

Source: California Energy Commission

11.5.9 Code in Practice

11.5.9.1 Garden Style Multifamily Case Study

The Garden Style Multifamily Case Study considers a new two-story garden style multifamily building in Burbank, California (Climate Zone [CZ] 9). This is a sample project created for training purposes, and it consists of 7,216 ft² of conditioned floor area with eight dwelling units and no common use areas. The case study tables in this chapter compare the proposed building mechanical system features to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Figure 53: Garden Style Multifamily Case Study: North (Rear) Elevation Showing Outdoor Condensers

Table 11-40: Garden Style Multifamily Mechanical Schedule

Split DX heat pumps: One heat pump per dwelling unit	**Cooling Efficiency**: 14 SEER **Cooling Output:** 1-1/2 ton, 17,700 Btuh total, 12,390 Btuh sensible **Heating Efficiency:** 8.2 HSPF **Heating Output:** 1-1/2 ton, 17,200 Btuh total	**Supply Fan:** 450 CFM 0.25 BHP MERV 13 2" filter	**Air Handler Location:** 1st Floor: Exterior closets 2nd Floor: Interior closets	**Distribution:** 1st Floor: R-8 Ducts between floors 2nd Floor: R-8 Ducts in attic
Bathroom exhaust fans: Continuous operation for whole dwelling unit IAQ ventilation	**EF-1** (1-bedroom units): 40 CFM each, 0.083 horsepower **EF-2** (2-bedroom units): 60 CFM each, 0.125 horsepower			
HVAC Controls	Programmable setback thermostats			

Source: California Energy Commission

Table 11-41: Garden Style Multifamily Case Study Compared to Mandatory and Prescriptive Mechanical System Requirements (Climate Zone 9)

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Multifamily Building	New two-story garden style multifamily building, eight dwelling units, no common use areas, Burbank, CA	§110.0, §110.1, §110.2, §160.2, §160.3 Title 20 Section 1605.1 Table C-3	§170.2(c), Table 170.2-K New multifamily building ≤ three stories, Climate Zone (CZ) 9	Case study Mandatory and Prescriptive compliance rated for each feature below as "Yes" (complies), "No" (does not comply) or "N/A" (not applicable). If "No", see compliance options provided.
Total Conditioned Floor Area (CFA)	7,216 ft²	7,216 ft²	7,216 ft²	
Fuel Type	Space Heating: Electricity Space Cooling: Electricity	No Mandatory fuel type requirements	Space Heating: Electricity Space Cooling: Electricity	Mandatory: NR Prescriptive: Yes
Equipment Type	Split DX heat pumps with air handlers in closets (1st floor exterior, 2nd floor interior) and condensers on pads outside, one 1.5 ton heat pump per dwelling unit	Meet or exceed Mandatory requirements for proposed HVAC system type	CZ 9: Electric heat pumps required for dwelling units in multifamily buildings ≤ three stories, HERS-verified refrigerant charge	
Heating Efficiency	8.2 HSPF	Meet or exceed current Federal minimum: HSPF ≥ 8.2	Meet or exceed current Federal minimum: HSPF ≥ 8.2	Mandatory: Yes Prescriptive: Yes
Cooling Efficiency	14.0 SEER	Meet or exceed current Federal minimum: SEER ≥14.0	Meet or exceed current Federal minimum: SEER ≥14.0	Mandatory: Yes Prescriptive: Yes

Table 11-42: Distribution, Ventilation and Verifications

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Distribution and Air Handler Location	1st Floor: R-8 ducts between floors, Air handler in unconditioned closet 2nd Floor: R-8 ducts in vented attic with R-30 ceiling insulation, Air handler in indirectly conditioned closet	Mandatory minimum R-6 for ducts in unconditioned space, HERS-verified duct leakage testing	HERS-verified ducts and air handler in conditioned space, OR Minimum R-8 ducts in Option B high performance vented attic and air handler in any location	Mandatory: Yes Prescriptive: No Compliance Options: 1. For 2nd floor ducts in attic: Upgrade to high performance attic (R-38 ceiling, R-19 roof, roofing type with air space) For 1st floor: Move ducts and air handler to conditioned space, and HERS verify. 2. Move all ducts and air handing units to conditioned space to meet Option C, and HERS verify 3. Performance Approach
Ventilation	Continuous bathroom exhaust fans for whole unit IAQ (triggers blower door envelope air-leakage testing): 1-Bedroom units: 40 CFM, 0.083 bhp 2-Bedroom units: 60 CFM, 0.125 bhp; AHAM/HVI certified kitchen hood over electric stovetop	Minimum whole dwelling unit ventilation per Equation 160.2-B: 1-Bedroom units: ≥ 38 CFM 2-Bedroom units: ≥ 55 CFM Mandatory HERS-verified: AHAM/HVI certified kitchen hood, IAQ ventilation, and enclosure air leakage	N/A	Mandatory: Yes Prescriptive: N/A
Verifications	Proposed building will have all required Mandatory and Prescriptive HERS verifications	Mandatory Kitchen hood Mandatory Duct testing Mandatory Fan efficacy/airflow rate Mandatory Heat Pump Rated Heating Capacity Mandatory IAQ Mandatory Enclosure Air Leakage	Prescriptive Refrigerant charge	Mandatory: Yes Prescriptive: Yes

Source: California Energy Commission

The proposed mechanical system meets all applicable mandatory requirements plus some of the relevant prescriptive requirements.

The split heat pump space heating and cooling equipment complies with the prescriptive heat pump requirement and meets the Federal mandatory minimum SEER and HSPF efficiency requirements. Note that the applicable heat pump heating and cooling efficiency requirements are listed in Title 20 Section 1605.1 Table C-3 for heat pumps under 65,000 Btuh, rather than in Table 110.2-B in Title 24, Part 6 which covers larger capacity heat pumps. Mandatory minimum whole dwelling unit ventilation for indoor air quality is calculated per Energy Code equation 160.2-B:

$Q_{tot} = (0.03 \times A_{floor}) + (7.5 \times (N_{br} + 1))$

Q_{tot} = Total required ventilation rate in CFM
A_{floor} = Dwelling unit floor area in ft²
N_{br} = Number of bedrooms (must be one or more)
1-bedroom units: (0.03 CFM/ft² x 750 ft²) + (7.5 CFM x (1 + 1)= 37.5 CFM

2-bedroom units: (0.03 CFM/ft² x 1080 ft²) + (7.5 CFM x (2 +1) = 54.9 CFM

HERS-verified continuous exhaust fan ventilation combined with HERS-verified limits to building envelope leakage, plus HERS-verified kitchen range hoods meet Mandatory ventilation requirements. Note that the kitchen hoods must be AHAM/HVI certified as meeting airflow rate or capture efficiency, and sound rating.

By contrast, the duct locations for the proposed systems as shown do not comply prescriptively. The building plans show the heat pump air handling units in the mechanical closets for each dwelling. On the first level the closets only open to the outside, so they are unconditioned space. R-8 ducts run from the air handlers up through the ceiling framing between levels to serve the conditioned spaces below. On the second level, the mechanical closets only open into the conditioned space of the dwelling units, so they are indirectly conditioned spaces. R-8 ducts run up from the air handlers into the vented attic which only has ceiling insulation but no roof insulation. These designs meet all mandatory requirements, but the Prescriptive path only allows two duct location options:

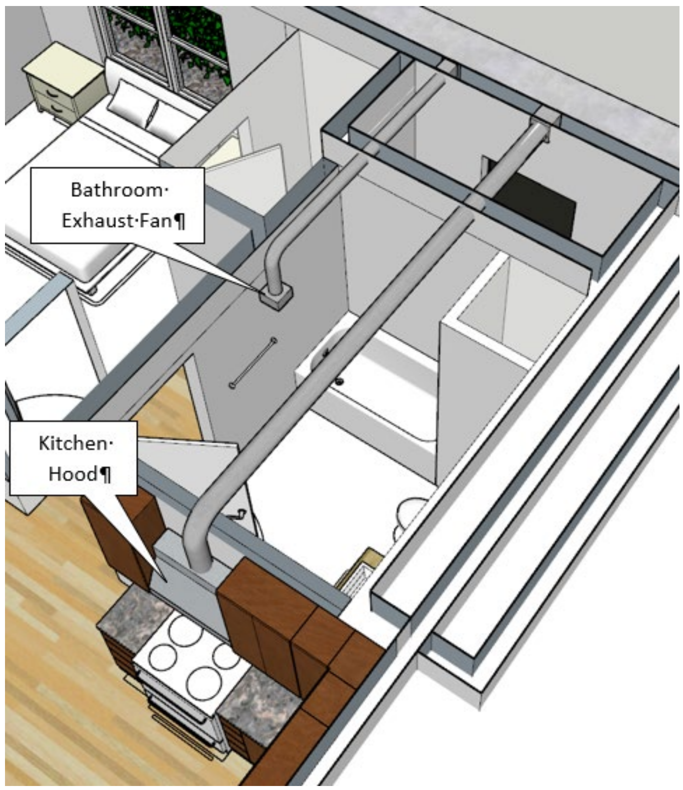
1. Ducts and air handling units both in conditioned space
2. R-8 ducts in a high performance attic designed to Prescriptive Option B with both ceiling and roof insulation

The Prescriptive Approach requires that a building meets all Prescriptive requirements. Unless the design team and owner are willing to change this particular building envelope to accommodate ducts and air handlers in conditioned space for the first floor, and either ducts in conditioned space or in a high performance attic for the second floor, the building will need to show compliance using the Performance Approach.

The Performance method allows trade-offs between different building features to offset components that do not comply prescriptively. There are also HVAC Performance compliance credit options available, such as:

- Higher efficiency equipment
- Variable capacity heat pump (VCHP)
- Low leakage air-handling unit (AHU)
- Pre-cooling
- ERV/HRV
- Whole house fan
- Central fan ventilation cooling system

Figure 54: Garden Style Multifamily: Bathroom Exhaust and Kitchen Hood Ducts



11.5.9.2 Mid-Rise Multifamily Case Study

The Mid-Rise Multifamily Case Study covers a new five-story multifamily building in Sacramento, California (Climate Zone [CZ] 12). This is a sample project created for training purposes, and it includes 112,044 ft² of conditioned floor area with 88 dwelling units, shared residential corridors, laundry rooms, fitness center and lounge, plus ground floor retail. The case study tables in this chapter compare the proposed building mechanical system features to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Figure 55: Mid-Rise Multifamily Case Study: Mechanical and Central DHW Roof Plan

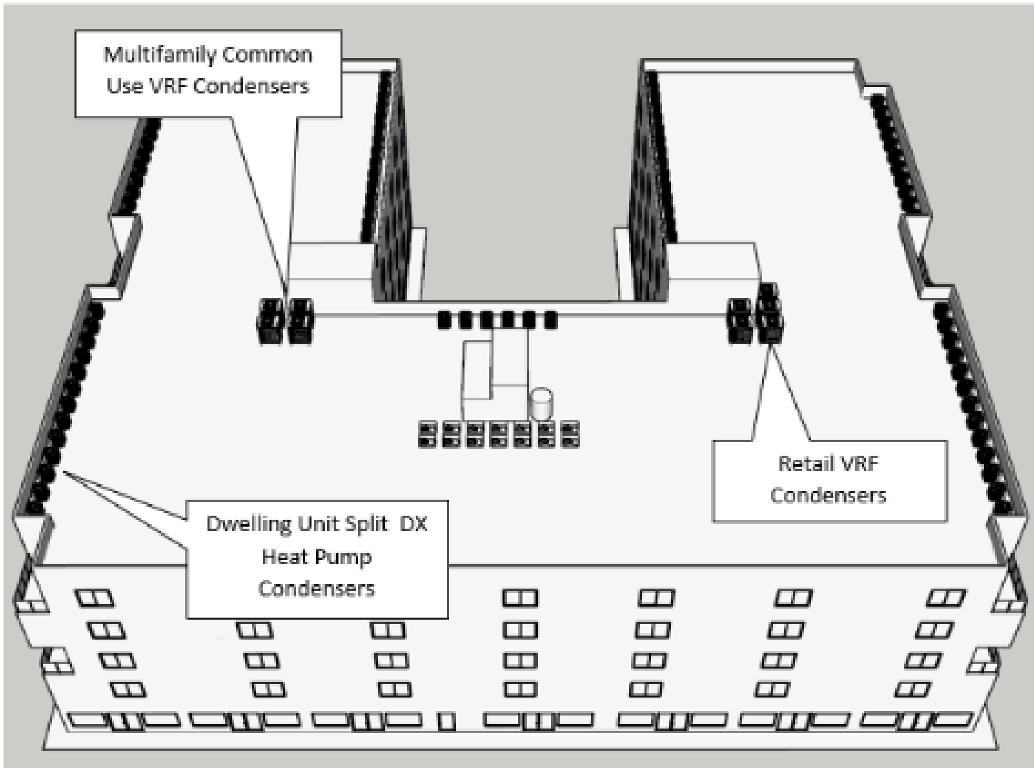


Figure 56: Mid-Rise Multifamily Case Study: 5th Floor Apartment Air Handler and Condenser

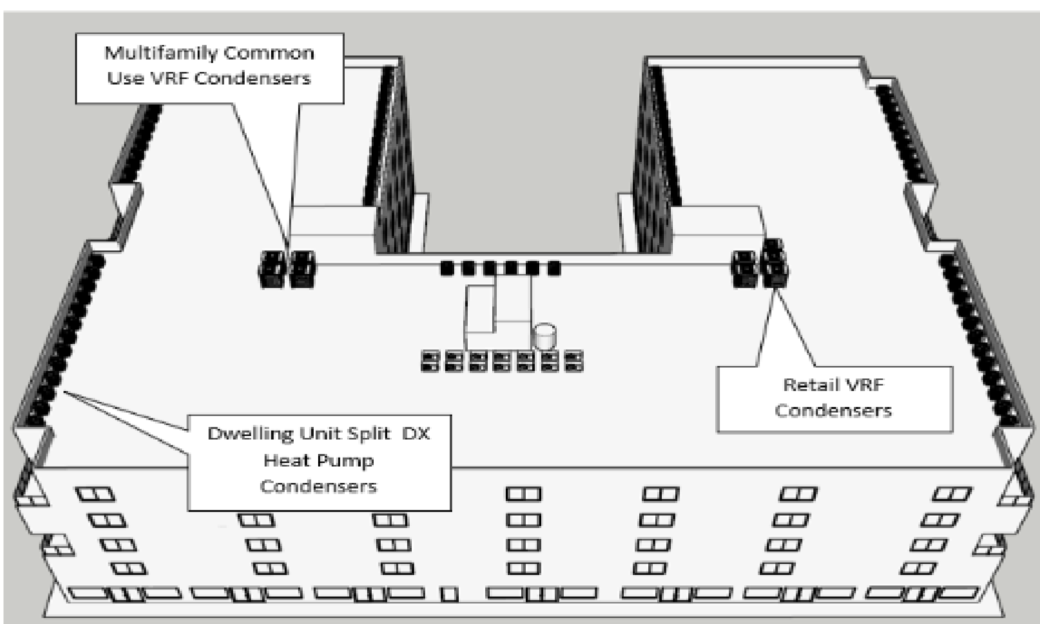


Table 11-43: Mid-Rise Multifamily Case Study Compared to Mandatory and Prescriptive Mechanical System Requirements (Climate Zone 12)

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Mid-Rise Multifamily Building	New five-story mid-rise multifamily building, 88 dwelling units, common use areas, ground floor retail, Sacramento, CA	§110.0, §110.1, §110.2, §120.1, §120.2, §120.3, §160.2, §160.3 Title 20 Section 1605.1 Table C-3	§170.2(c), Table 170.2-K Section 140.4 New mixed occupancy multifamily plus nonresidential building ≥ four stories, Climate Zone (CZ) 12	Case study Mandatory and Prescriptive compliance rated for each feature below as “Yes” (complies), “No” (does not comply) or “N/A” (not applicable). If “No”, see compliance options provided.
Conditioned Floor Area (CFA)	Dwelling Units: 78,384 ft²	78,384 ft²	§170.2(c)3	
	Common Use Multifamily: 17,487 ft²	17,487 ft² 160.3(b)	§170.2(c)1-2	
	Nonresidential: 16,173 ft²	16,173 ft²	§140.4	
	Total: 112,044 ft²	112,044 ft²		
Total Percent Multifamily in Mixed Occupancy Building	(78,384 + 17,487)/ 112,044 = 85.6%	Mandatory requirements for each occupancy type	Because multifamily is ≥ 80% of total CFA, the whole building has the option of complying with multifamily Prescriptive, or could comply by separate occupancies	

Source: California Energy Commission

Figure 57: Section 100.0(f) Exception 1 for Mixed Occupancy

Mixed Occupancy. When a building is designed and constructed for more than one type of occupancy (residential and nonresidential), the space for each occupancy shall meet the provisions of Part 6 applicable to that occupancy.

EXCEPTION 1 to Section 100.0(f): If one occupancy constitutes at least 80 percent of the conditioned floor area of the building, the entire building envelope, HVAC, and water heating may be designed to comply with the provisions of Part 6 applicable to that occupancy, provided that the applicable lighting requirements in Sections 140.6 through 140.8, ~~or~~ 150.0(k), or 160.5 and 170.2(e) are met for each occupancy and space, and mandatory measures in Sections 110.0 through 130.5, ~~and~~ 150.0, and 160.0 through 160.9 are met for each occupancy and space.

Table 11-44: Fuel Type, Equipment Type and Efficiency

Case Study Equipment Types and Locations
1st Floor: Mixed Occupancy: Retail (Nonresidential) and 1st -5th Floors: Multifamily Common Use (MF CU): Variable refrigerant flow (VRF) multi-split air source heat pumps, condensers on the roof, VRF heat pump fan coil units installed for each zone, economizers for FCUs with cooling capacity > 33,000 Btuh, Retail: No ducts, MF CU: Ducts in conditioned space 2nd-5th Floors: Multifamily Dwelling Units (MF DU): Split DX heat pumps with air handlers in interior closets and condensers on roof, ducts in conditioned space, one 1.5 ton heat pump for each studio, 1-bedroom and 2-bedroom dwelling unit, one 2 ton heat pump for each 3-bedroom dwelling unit
Fuel Type, Equipment Type and Efficiency

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Fuel Type: Space Heating	MF DU: Electricity	No requirement	Electric heat pump	Mandatory: NR Prescriptive: Yes
	MF CU: Electricity	No requirement	No requirement	Mandatory: NR Prescriptive: NR
	Retail: Electricity	No requirement	No requirement	Mandatory: NR Prescriptive: NR
Fuel Type: Space Cooling	MF DU: Electricity	No requirement	Electric heat pump	Mandatory: NR Prescriptive: Yes
	MF CU: Electricity	No requirement	No requirement	Mandatory: NR Prescriptive: NR

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
	Retail: Electricity	No requirement	No requirement	Mandatory: NR Prescriptive: NR
Equipment Type Note: Proposed systems are designed to meet all applicable Mandatory requirement	MF DU: Split DX heat pumps (HP)	Meet or exceed all applicable Mandatory requirements	CZ 12: Electric heat pumps with verified refrigerant charge required	MF DU: Mandatory: Yes Prescriptive: Yes
	MF CU: VRF HP ≥ 240 kBtuh cooling, sized to meet design loads	VRF heating rating condition: 47°F DB and 43°F WB outdoor air	Sized to meet design heating and cooling loads per 170.2(c)1-2	MF CU: Mandatory: Yes Prescriptive: Yes
	Retail: VRF HP ≥ 240 kBtuh cooling, sized to meet design loads	VRF heating rating condition: 47°F DB and 43°F WB outdoor air	Sized to meet design heating and cooling loads per 140.4(a)1	Retail: Mandatory: Yes Prescriptive: Yes
Heating Efficiency: Meet or exceed Federal minimums	MF DU: Split HP: 8.2 HSPF	HSPF ≥ 8.2	HSPF ≥ 8.2	Mandatory: Yes Prescriptive: Yes
	MF CU: VRF HP: 3.2 COP	COP ≥ 3.2	COP ≥ 3.2	Mandatory: Yes Prescriptive: Yes
	Retail: VRF HP: 3.2 COP	COP ≥ 3.2	COP ≥ 3.2	Mandatory: Yes Prescriptive: Yes
Cooling Efficiency: Meet or exceed Federal minimums	MF DU: Split HP: 14.0 SEER	SEER ≥ 14.0	SEER ≥ 14.0	Mandatory: Yes Prescriptive: Yes
	MF CU: VRF HP: 9.5 EER	EER ≥ 9.5	EER ≥ 9.5	Mandatory: Yes Prescriptive: Yes
	Retail: VRF HP: 9.5 EER	EER ≥ 9.5	EER ≥ 9.5	Mandatory: Yes Prescriptive: Yes

Source: California Energy Commission

Table 11-45: Distribution, Air Handlers and Fan Systems

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Distribution and Air Handlers	MF DU: Verified uninsulated ducts in conditioned space, air handlers in indirectly conditioned closets, refrigerant line pipe insulation	Mandatory verification of uninsulated ducts in conditioned space, Pipe insulation for refrigerant distribution systems per 160.3(c)1	No requirement for ducts in conditioned space	Mandatory: Yes Prescriptive: Yes
	MF CU: R-4.2 ducts in indirectly conditioned space, fan coil units (FCUs) in indirectly conditioned space, economizers for FCUs with > 33,000 Btuh cooling, refrigerant line pipe insulation	Pipe insulation for refrigerant distribution systems per 160.3(c)1 Minimum R-4.2 duct insulation or ducts in directly conditioned space	Economizers required for air handlers with > 33,000 Btuh cooling	Mandatory: Yes Prescriptive: Yes
	Retail: Ductless, FCUs in indirectly conditioned space, economizers for FCUs with > 33,000 Btuh cooling, refrigerant line pipe insulation	Pipe insulation for refrigerant distribution systems per 120.3	Economizers required for air handlers with > 33,000 Btuh cooling	Mandatory: Yes Prescriptive: Yes
Fan Systems	MF DU: See ventilation section below	See Ventilation section below	See Ventilation section below	Mandatory: N/A Prescriptive: N/A
	MF CU: All proposed fan systems, including VRF HP FCUs and DOAS ERV, with any fan or fan array ≥ 1 kW will be designed so that Fan kWdesign system ≤ Fan kWbudget per 170.2(c)4Aia. Fan motors < 1 hp and ≥ 1/12 hp to meet 170.2(c)4iii		170.2(c)4Ai: Each fan system with any fan or fan array ≥ 1 kW: Fan kWdesign system ≤ Fan kWbudget per 170.2(c)4Aia 170.2(c)4Aiii: Efficiency requirements for fan motors < 1 hp and ≥ 1/12 hp	Mandatory: N/A Prescriptive: Yes
	Retail: Similar to MF CU, but for 140.4(c)1 and 3		Similar to MF CU, but for 140.4(c)1 and 3	Mandatory: N/A Prescriptive: Yes

Table 11-46: Ventilation and Verifications

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Ventilation	MF DU: Balanced Energy Recovery Ventilation (ERV): Sensible Recovery Efficiency = 0.67 Fan Efficacy = 0.60 W/CFM Studios and 1-Bedroom units: 40 CFM, 0.032 bhp 2-Bedroom units: 60 CFM, 0.048 bhp; 3-Bedroom units: 75 CFM, 0.060 bhp AHAM/HVI certified kitchen hood over electric stovetop	MF DU: Balanced ERV: Fan Efficacy ≤ 1 W/CFM Minimum whole dwelling unit ventilation per Equation 160.2-B: Studios: ≥ 32 CFM 1-Bedroom units: ≥ 38 CFM 2-Bedroom units: ≥ 55 CFM 3-Bedroom units: ≥ 73 CFM Mandatory HERS-verified: AHAM/HVI certified kitchen hood, IAQ ventilation	MF DU: ERV: Sensible Recovery Efficiency ≥ 0.67 Fan Efficacy ≤ 0.60 W/CFM	Mandatory: Yes Prescriptive: Yes
	MF CU: DOAS ERV: 3,100 CFM Working with separate VRF HP system, meets 170.2(c)4O; Demand Control Ventilation (DCV)	Minimum total MF CU ventilation per Equation 160.2-G: ≥ 3,033 CFM	170.2(c)4N: DOAS with separate space conditioning to meet 170.2(c)4O Exhaust Air Heat Recovery. If airflow > 1,000 CFM require DCV	Mandatory: Yes Prescriptive: Yes
	Retail: DOAS ERV: 4,100 CFM (Other features same as MF CU)	Minimum total retail ventilation per Equation 120.1-F: ≥ 4,043 CFM	Same as MF CU	Mandatory: Yes Prescriptive: Yes
Verifications	Proposed building will have all required Mandatory and Prescriptive verifications	MF DU (Installing Contractor) Mandatory Duct testing Mandatory Ducts in conditioned space Mandatory Fan efficacy/airflow rate Mandatory Heat Pump Rated Heating Capacity Mandatory ERV/HRV fan efficacy (when present) MF DU (HERS) Mandatory Kitchen hood	Prescriptive Refrigerant charge Balanced Ventilation Systems (if present) ERV/HRV recovery efficiency (if present) ERV/HRV recovery efficiency above mandatory min. (if present) ERV/HRV recovery bypass (if present)	Mandatory: Yes Prescriptive: Yes

		Mandatory IAQ MF CU and Retail (ATT) Mandatory Airflow Mandatory Demand Shed Controls Mandatory EMCS Occupancy Sensor Zone Controls (corridors)		

Source: California Energy Commission

Table 11-47: Mid-Rise Multifamily Mechanical Schedule: Dwelling Units

Split DX heat pumps: One heat pump per dwelling unit: **1.5 tons** for studios, 1-bedroom and 2-bedroom units **2 tons** for 3-bedroom units	**Cooling Efficiency**: 14 SEER **Heating Efficiency:** 8.2 HSPF **Cooling Output:** **1.5 ton units:** 17,700 Btuh total, 12,390 Btuh sensible **2 ton units:** 22,200 Btuh total, 15,540 Btuh sensible **Heating Output:** **1.5 ton units:** 17,200 Btuh total **2 ton units:** 22,000 Btuh total	**Supply Fan:** **1.5 ton:** 525 CFM 0.40 BHP **2 ton:** 700 CFM 0.50 BHP **All:** MERV 13 2" filter	Air Handler Location: Interior closets	**Distribution:** Uninsulated ducts in conditioned space verified by installer

Notes on System:

- ERV Systems: Providing dwelling unit ventilation
- Balanced Energy Recovery Ventilation (ERV): Studios and 1-Bedroom units: 40 CFM, 0.032 bhp. 2-Bedroom units: 60 CFM, 0.048 bhp; 3-Bedroom units: 75 CFM, 0.060 bhp
- Kitchen hood: Installed over induction electric cooktops in each dwelling unit
- Bathroom exhaust fans: 70 CFM each, 0.055 bhp
- HVAC Controls: Programmable setback thermostats

Source: California Energy Commission

Table 11-48: Mid-Rise Multifamily Mechanical Schedule: Multifamily Common Use and Retail

Area Served	QTY	Equipment	Distribution
All 1st Floor Retail Total Outside Air ≥ 4,043 CFM	1	VRF Condenser: Cooling Output: 364,000 Btuh	
Retail Zones Total Outside Air ≥ 4,043 CFM	11	(1) VRF Heat pump FCU per zone: Cooling Output: 36,100 Btuh Heating Output: 48,100 Btuh Economizer	Ductless
All Multifamily Common Use Total Outside Air ≥ 3,033 CFM	1	VRF Condenser: Cooling Output: 246,000 Btuh	
MF CU Zones:		(1) VRF Heat pump FCU per zone:	

Area Served	QTY	Equipment	Distribution
1st Floor: Leasing Outside Air ≥ 216 CFM	1	Cooling Output: 26,800 Btuh Heating Output: 36,200 Btuh	R-4.2 Ducts in ind. conditioned
1st Floor: Lounge/Rec Outside Air ≥ 585 CFM	1	Cooling Output: 36,100 Btuh Heating Output: 48,100 Btuh Economizer	R-4.2 Ducts in indirectly conditioned
1st Floor: Fitness Center Outside Air ≥ 135 CFM	1	Cooling Output: 18,000 Btuh Heating Output: 19,100 Btuh	R-4.2 Ducts in ind. conditioned
1st Floor: Business Center Outside Air ≥ 54 CFM	1	Cooling Output: 9,300 Btuh Heating Output: 9,600 Btuh	R-4.2 Ducts in ind. conditioned
1st - 4h: Corridor/Stairs/Support 1st : Outside Air ≥ 387 CFM 2nd 4th: Outside Air per Zone ≥ 414 CFM	4	Cooling Output: 30,800 Btuh Heating Output: 36,200 Btuh	R-4.2 Ducts in indirectly conditioned
5th: Corridor/Stairs/Support Outside Air ≥ 414 CFM	1	Cooling Output: 33,600 Btuh Heating Output: 42,000 Btuh Economizer	R-4.2 Ducts in indirectly conditioned

Source: California Energy Commission

VRF systems: Separate multi-split VRF heat pump systems serving retail and multifamily common use areas

Dedicated Outdoor Air Systems (DOAS): MERV 13 Filters, Demand Control Ventilation

Retail ERV: Outdoor Air Volume: 4,100 CFM, Supply Fan: 2 hp, Exhaust Air Volume: 4,100 CFM, Exhaust Fan: 2 hp

HVAC Controls: Programmable setback thermostats for each zone, occupant sensor shut-off controls in corridors and stairwells with partial OFF lighting controls, automatic time switch shut-off controls in other zones

MF CU ERV: Outdoor Air Volume: 3,100 CFM, Supply Fan: 1.5 hp, Exhaust Air Volume: 3,100 CFM, Exhaust Fan: 1.5 hp

This mid-rise multifamily case study has different types of mechanical systems for the dwelling units versus the multifamily common use areas and retail zones.

The dwelling unit split heat pump space heating and cooling equipment complies with the Prescriptive heat pump requirement and meets the Federal Mandatory minimum SEER and HSPF efficiency requirements. Note that the applicable heat pump heating and cooling efficiency requirements are listed in Title 20 Section 1605.1 Table C-3 for heat pumps under 65,000 Btuh. Each system consists of a heat pump air handler located in a dwelling unit and a separate condenser located on the roof. Since there are 88 total dwelling units with split heat pumps, there are 88 condensers located on the roof. In this case study, those condensers are placed around the roof perimeter next to the parapets to leave room for the required solar photovoltaic (PV) panels.

The multifamily common use areas and the retail spaces are served by VRF heat pump equipment with central condensing units on the roof and VRF heat pump fan coil units in each zone. The selected equipment meets the Federal Mandatory minimum heating and cooling efficiency requirements found in Energy Code Table

110.2-H for VRF air cooled systems. There are different cooling efficiency requirements for VRF systems with different cooling capacities ranging from less than 65,000 Btuh to greater than or equal to 240,000 Btuh. There are also different heating efficiency requirements based on cooling, not heating, capacities ranging from less than 65,000 Btuh to 135,000 Btuh or more. Note that while the VRF fan coil units all have cooling capacities less than 65,000 Btuh, the two different VRF condensers for retail and common use areas are both over 240,000 Btuh. The efficiencies in Table 110.2-H are based on the condenser cooling capacity, not that for the fan coil units. Knowing that, Table 110.2-H shows that these particular VRF systems must meet or exceed a cooling efficiency of 9.5 EER and a heating efficiency of 3.2 COP.

Supplying mandatory ventilation outside air is handled differently for the residences compared to the common use areas and retail zones. The dwelling unit ventilation system includes three main components within each residence:

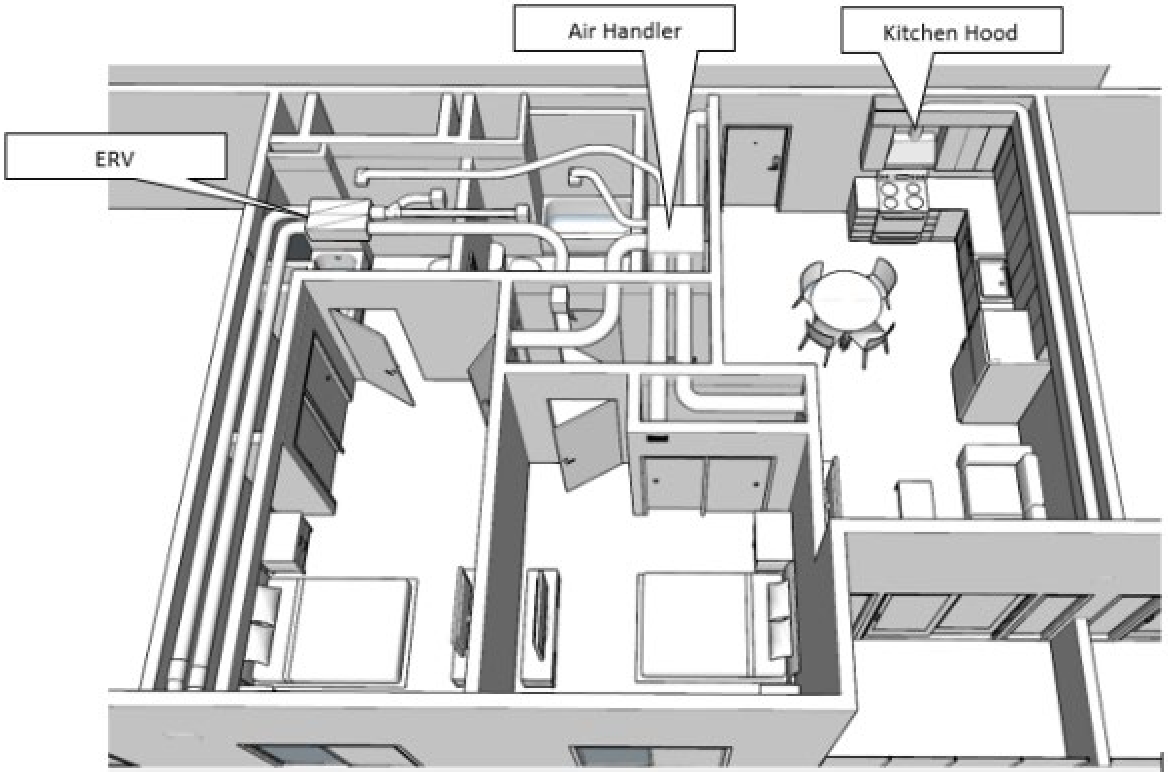
- The primary air handler in each unit connected to ducts in conditioned space that deliver heated and cooled air throughout the residence
- A balanced energy recovery ventilator or ERV that supplies outdoor air and exhausts indoor air
- The kitchen hood installed over the electric induction cooktop that exhausts cooking fumes directly to the outside

By contrast, the multifamily common use areas and retail spaces have the following ventilation components:

- Central ERV dedicated outside air systems (DOAS) – one that delivers outside air to all the retail spaces and another that delivers outside air to all the multifamily common use areas. Since these systems are ERVs, they also exhaust the same amount of indoor air from the zones they serve.
- VRF heat pump fan coil units in each zone that deliver heated and cooled air within the space. The retail fan coil units are ductless, so they deliver conditioned air from one central location within each store. The common use fan coil units deliver air through ducting throughout each space.

Overall, the proposed mechanical systems meet all applicable mandatory requirements and prescriptive requirements, so the proposed systems comply prescriptively as designed.

Figure 58: Mid-Rise Multifamily: 5th Floor Apartment HVAC Supply, ERV and Kitchen Hood Layout with Ducts



11.6 Water Heating Requirements

Chapter 11.7.5 describes the compliance requirements for domestic water heating for newly constructed multifamily dwellings. This chapter describes common water heater types, and hot water distribution system designs. For service hot water systems serving common use area and nonresidential spaces within a multifamily building, see Chapter 4.8.

Table 11-49 provides an overview of the location of the water heating requirements in the Energy Code by system building type and where descriptions reside in this document.

Table 11-49: Overview of Multifamily Water Heating Requirements

Types	Mandatory Requirements Standards Section	Mandatory Requirements Manual Section	Prescriptive Requirements Standards Section	Prescriptive Requirements Manual Section	Performance Requirements Standards Section	Performance Requirements Manual Section
System serving individual dwelling units only; Systems serving common use areas without a recirculation loop	§110.3. §160.4	11.7.5; 11.7.6.10;	§170.2(d) 1	11.7.6.10; 11.7.6.20	§170.1	11.7.6.10: 11.7.6.20;
Systems serving multiple dwelling units; Systems serving common use areas with a recirculation loop	§110.3. §160.4 except (a)	11.7.5; 11.7.6.10; 11.7.7.20	§170.2(d). §170.2(d) 2 through 4	11.7.7.10; 11.7.7.20	§170.1	11.7.7.10; 11.7.7.20

Source: California Energy Commission

11.6.1 What's New for the 2022 Energy Code

This section summarizes changes to the requirements for multifamily water heating for the *2022 Energy Code*. Water heating requirements are organized by and based on whether a water heating system services individual versus multiple dwelling units.

11.6.1.1 Mandatory Requirements

For systems serving individual dwelling units:

For systems serving multiple dwelling units:

- Increase in pipe insulation requirements for hot water pipes two inches and larger.

For system serving common use area:

11.6.1.2 Prescriptive Requirements

For water heating systems serving individual dwelling units:

- 240 volt heat pump water heaters were added as a prescriptive path, with additional efficiency features required for select climate zones. A NEEA Advanced Water Heater Specification Tier 3 or higher heat pump water heater can be used also.

- Gas storage water heater is removed as a prescriptive path. Instantaneous gas water heaters are allowed prescriptively.

  For central water heating systems serving dwelling units:

- A prescriptive pathway for central heat pump water heating systems serving multiple dwelling units. The prescriptive pathway includes basic plumbing configuration and control requirements to ensure system performance. It also includes design documentation requirements that are part of JA 14.
- Updates to central gas or propane storage system call for minimum ninety percent thermal efficiency for system at or larger than one MMBtu/h for Climate Zones 1 through 9. A solar thermal system with minimum solar savings fraction is required in conjunction.

11.6.1.3 Performance Approach

- The central water heating system energy budget for the performance approach now has a gas or electric baseline based on the proposed water heater type. For gas-fueled water heaters, the energy budget is based on the performance of a gas storage water heater system. For electric water heaters (both electric resistance and heat pump heaters), the energy budget is based on the performance of a central HPWH system. The gas and electric water heaters used in the baseline must meet the minimum requirements in California's Title 20 Appliance Efficiency Regulations Section 1605.1(f) for federally regulated appliances.
- For central HPWH systems to comply using the performance method, central HPWH products to be certified to the Energy Commission and specifies design documentation requirements per JA 14 qualification requirements.

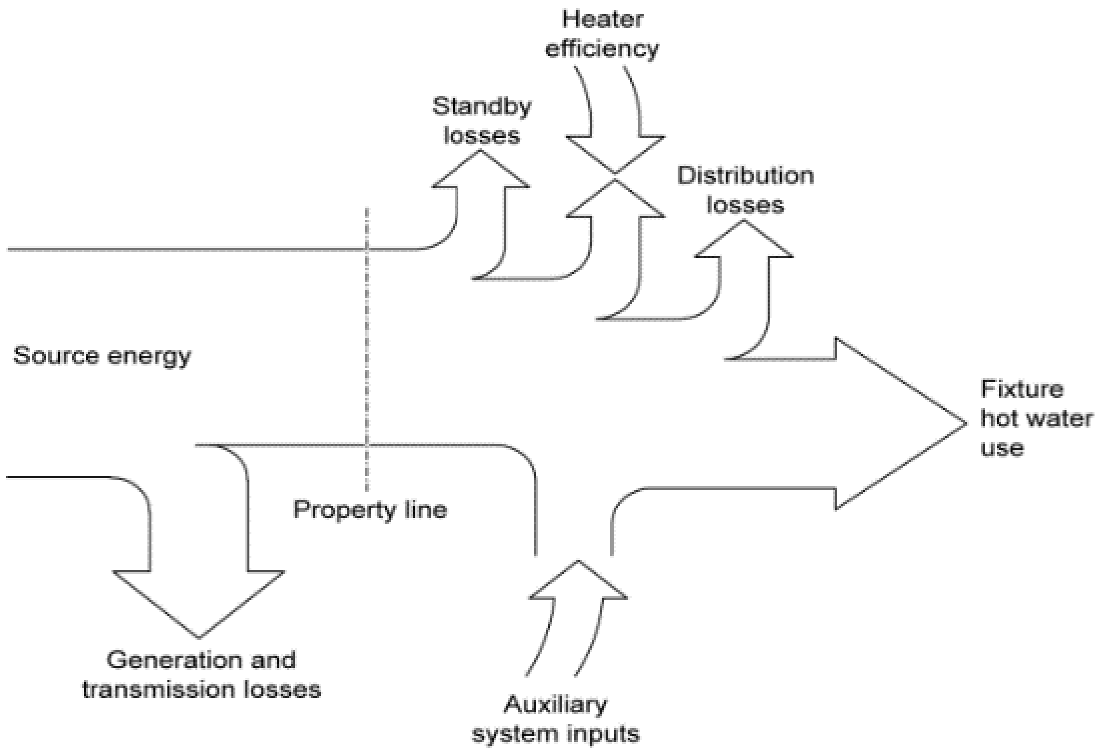
11.6.2 Water Heating Energy

Total energy use associated with water heating consists of fixture hot water use, heater inefficiencies, standby losses, and distribution system losses. Figure 11-59 below shows the energy flows that constitute water heating energy usage. Hot water draws at the end use points (for example, faucets, showers, etc.) represent the useful energy consumed. In most cases, hot water usage represents the largest fraction of water heating energy consumption, although in situations when there are very few hot water draws, standby losses from a standard gas storage water heater and the hot water distribution system can exceed the quantity of useful energy consumed at the end point.

Energy impacts associated with the hot water distribution system vary widely based on the type of system, quality of insulation and installation, building and plumbing design, and hot water use patterns. Distribution losses in a typical water heating system serving individual dwelling units may be as much as 30% of the total energy used for water heating. This figure drops to lower than 10% of total water heating energy use for dwelling units with compact hot water distribution. In a typical multifamily building where a centralized system is installed, distribution losses can account for more than 30% of total water heating energy use.

In this compliance manual, the hot water load at the end use points is defined as the *Primary Water Heating Load,* and the hot water load due to heat loss in the distribution loop is defined as *Temperature Maintenance Load*. For central water heating systems with large recirculation loop, designers must consider both types of load for equipment sizing and plumbing configuration.

Figure 11-59: Water Heating Energy Flow Representation



11.6.3 Multifamily Water Heating Equipment

This section describes various water heating systems and equipment types for multifamily buildings. Descriptions of applicable code requirements begin in Section 11.7.5 and on.

There are several types of water heaters for multifamily buildings, as described below. The most common water heaters serving individual dwelling units are consumer gas storage, instantaneous gas water heaters, and heat pump water heaters. For systems serving multiple dwelling units and common use area, two options are commonly used: 1) a central domestic hot water (DHW) system with one or more commercial storage water heaters or 2) one or more boilers coupled with a storage tank to serve the entire building.

To comply with the Energy Code using either the prescriptive or performance approach, the water heater must meet the federal and/or the California Appliance Efficiency Regulations (Title 20).

11.6.3.1 Dwelling Unit Instantaneous Water Heaters

Instantaneous water heaters, commonly referred to as *tankless* or *on-demand*, heat water using natural gas, electricity, or propane. These units do not have a tank for storing heated water, but instead use a sensor that detects the flow of water over the heat exchanger that initiates the heating element (typical volumes around 0.5 gallons). Instantaneous units can deliver water at a controlled temperature of less than 180ºF. The input rating for gas instantaneous water heaters ranges between 50,000 and 200,000 BTU per hour (at least 4,000 BTU per hour per gallon of stored water) with a storage capacity of less than two gallons.

Instantaneous water heaters require an electrical connection for controls and the combustion air blower, a direct or power venting system. Instantaneous gas water heaters require a larger gas line (typical input ratings of 140,000 to 200,000 BTU/hr) than storage gas water heaters.

Electric instantaneous water heaters are not generally designed for use with solar water heating systems or as heat sources for indirect-fired water heaters. They are also typically inappropriate for use with recirculation systems. Electric instantaneous water heaters are not allowed through the prescriptive approach but can be modeled in the performance approach, although it is difficult to show compliance without significant upgrades to other building components.

To comply prescriptively with the *Energy Code*, a user can choose to install a gas or propane instantaneous water heater that meets the minimum efficiency requirements of California's *Title 20 Appliance Efficiency Regulations*. The equipment is limited to an input of 200,000 BTU per hour and no storage tank.

11.6.3.2 Storage Water Heater

11.6.3.3 Consumer Storage Water Heaters

Storage water heaters use gas (natural gas or propane), electricity, or oil to heat and store water at a thermostatically controlled temperature (less than 180º F) for delivery on demand. Federal appliance efficiency standards differentiate storage water heaters based on whether the rated storage volume is greater than 55 gallons or less than or equal to 55 gallons.

The U.S. Department of Energy (DOE) classifies consumer gas water heaters as having an input of 75,000 BTU per hour or less and has a storage capacity ranging between 20 and 100 gallons. A basic gas storage water heater is composed of a standing pilot ignition system, a burner, a combustion chamber, a flue baffle, a flue, an insulated water tank, a cold water inlet and hot water outlet, a sacrificial anode, a gas valve, a temperature and pressure relief valve, a thermostat, heat traps, and an outer case.

The DOE classifies consumer electric storage water heaters as having an input of 12 kilowatt (kW) or less and have a storage capacity ranging between 20 and 120 gallons. A basic electric storage water heater differs from gas water heaters by using an electric resistance heating element. As noted in this chapter, electric storage water heaters are not allowed through the prescriptive approach but can be installed using the performance approach.

In 2015, the DOE added a new category of water heaters called *grid-enabled water heaters* defined as an electric resistance water heater that has a rated storage tank volume of more than 75 gallons and is manufactured on or after April 16, 2015. The water heater must have an activation lock at the point of manufacture and is intended for use only as part of an electric thermal storage or demand response (DR) program.

11.6.3.4 Residential-Duty Commercial Water Heater

Residential-duty commercial water heater is essentially a commercial water heater that can be legally installed in a residential dwelling unit. It is defined in the Federal Code of Regulations (10 CFR 431.102) as any gas-fired, electric, or oil storage or instantaneous commercial water heater that meets the following conditions:

1. Uses a single-phase external power supply for models that require electricity.
2. Is not designed to provide outlet hot water at temperatures greater than 180°F.
3. Is not excluded by the specified limitations regarding rated input and storage capacity as described in Table 11-50 below. In other words, a residential-duty commercial water heater must have rated input and rated storage volume below the value listed in Table 11-50.

Table 11-50: Capacity Limitations for Defining Commercial Water Heaters – Heaters with Specifications below These Thresholds are "Residential-Duty"

Water Heater Type	Indicator of Nonresidential Application
Gas-Fired Storage	Rated input >105 kBTU/h; Rated storage volume >120 gallons.
Oil-Fired Storage	Rated input >140 kBTU/h; Rated storage volume >120 gallons.
Electric Instantaneous	Rated input >58.6 kW; Rated storage volume >2 gallons.

Source: U.S. Department of Energy (2014). "Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Residential and Commercial Water Heaters; Final Rule." http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-TP-0042-0082

Residential-duty commercial water heaters are rated in uniform energy factor (UEF) and are allowed through the prescriptive approach. They can also be installed using the performance approach serving either individual or multiple dwelling units, though use with multiple dwelling units trigger solar water heating requirements and potentially recirculation requirements if serving more than eight dwelling units.

11.6.3.5 Hot Water Supply Boiler

A *hot water supply boiler* is water heating equipment with a heat input rate from 300 to 12,500 kBTU per hour and at least 4,000 BTU per hour per gallon of stored water. A hot water boiler should have either the temperature or pressure control necessary for heating potable water for purposes other than space heating, or the boiler manufacturer's literature should indicate that the intended uses of the boiler include heating potable water for purposes other than space heating. A hot water boiler could be fueled by oil or gas, and it must adhere to the minimum thermal efficiency and maximum standby loss as described in California's *Title 20 Appliance Efficiency Regulations*.

Boilers are typically used for both central space heating and water heating in multifamily buildings and require one or more unfired storage tanks as part of the system. Careful attention should be given to the layout of these systems, due to the potential for high energy losses between the boiler and storage tanks.

11.6.3.6 Heat Pump Water Heaters

This section describes heat pump water heater equipment for multifamily buildings. Descriptions of applicable code requirements begin in Section 11.7.5 and on.

An HPWH is an electric water heater that works like an air condition cycle in reverse. It uses a compressor to transfer heat from the surrounding air to the water tank. It includes all necessary auxiliary equipment such as fans, storage tanks, pumps, or controls. Typically, HPWHs include backup electric resistance elements to ensure hot water delivery when the air temperature is too cold, or the hot water demand is too high. A few models use larger compressors to avoid the need for resistance elements.

The performance of HPWHs depends heavily on air temperature because they rely on extracting heat from the air. Climate conditions and different installation locations, such as a garage or a vented outdoor closet, have an impact on performance. HPWHs are most efficient in warmer climates. In addition to air temperature sensitivity, HPWH performance is affected by cold water inlet temperatures, as introduction and mixing of inlet water during larger draws may trigger second stage electric resistance heating in the tank.

There are two basic configurations of a HPWH system's storage tank and heat pump.

- Unitary heat pump with integrated storage (commonly used for individual systems)
- Split heat pump with separate storage tank(s)

A simple and readily available is unitary heat pump with integrated storage. These units are single package, and they physically resemble the size and form of traditional residential tank-type gas water heaters. Most integrated heat pumps are sized for individual or multiple dwelling unit applications. Multiple heat pumps can be combined to create a larger system without recirculation, referred to as a clustered design.

Split heat pumps with separate storage tanks are larger capacity products suitable for multifamily central HPWH applications. These heat pumps range in heating capacity from 15,000 Btu/hr to 250,000 Btu/hr. Central system designs often bundle modular compressors for combined capacities of over 2,000,000 Btu/hr.

For split systems, the designer needs to separately size and specify the heat pump, storage tanks, and other associated components. Without turnkey packaged central HPWH solutions, manufacturers typically work closely with the design engineers for customized matching of their various product components to the design condition.

The Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heater Specification[4] (Spec) was developed to address critical performance and comfort issues of individual HPWH in colder climates. The NEEA Spec incorporates tiers of various product performance and configuration. A NEEA Tier 3 or higher HPWH can be used to meet the prescriptive requirements.

HPWHs use a range of refrigerant types, each with different thermodynamic properties, which impact their operation pressure, temperature requirements, and efficiency to move heat. This consequently impacts design and installation approaches such as the plumbing configuration, equipment location, and ventilation air quantity. The refrigerant can also dictate whether electric resistance backup, integrated or otherwise, is needed. A given refrigerant can achieve a certain heat transfer rate at an achievable pressure. If the heat transfer rate is insufficient under low outdoor temperatures or during certain draw periods (e.g., high total hot water usage), then electric resistance backup heating becomes necessary. The refrigerant likewise may be able to operate more efficiently at a higher pressure, negating the need for back up electric resistance; however, that pressure may not be achievable in the equipment’s system. Therefore, the properties of the refrigerant play a big role in system design and capability.

The global warming potential (GWP) metric differentiates refrigerants based on their environmental destructiveness. The California Air Resources Board (CARB) regulations prohibit or are phasing out the use of high GWP refrigerants in a range of equipment types and end uses. CARB’s regulations will drive technological development of low GWP refrigerant systems and impact HPWH product availability, design considerations, and efficiency performance.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) classifies refrigerant safety in terms of toxicity and flammability levels in ASHRAE Standard 34 (2019) as shown in Figure 11-60. Lower toxicity refrigerants displace oxygen if not properly managed, and ASHRAE develop a refrigerant

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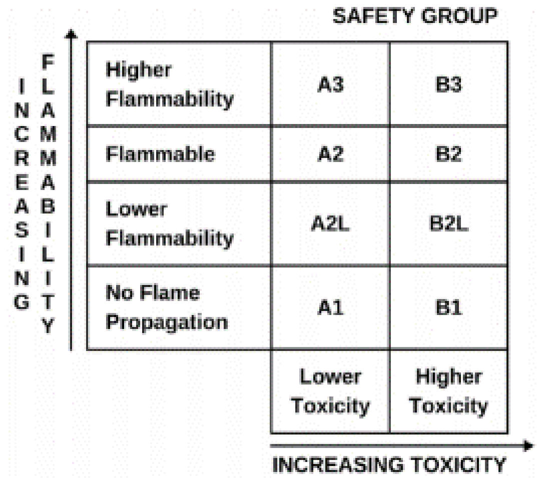
[4] https://neea.org/img/documents/qualified-products-list.pdf

concentration limit (RCL) to ensure the equipment and the space that houses the equipment address these risks. Mitigation strategies include locating the equipment outside or providing adequate circulation or ventilation to ensure the concentration does not exceed the RCL (which has a safety margin built in).

Figure 11-60: ASHRAE Safety Classification of Refrigerants



11.6.3.7 Design Capacity and Storage Sizing

HPWH functions are fundamentally different than gas water heaters in terms of thermal performance characteristics, operating conditions, and recovery capacity. A gas water heater can heat water quickly with a high instantaneous heating capacity. A design approach with large heating capacity, but small storage volume, will improve system efficiency by reducing the heat loss associated with water storage. The incremental costs for large capacity gas water heaters are minimal such that this traditional sizing approach often results in a cost-effective solution. Gas water heaters typically fire for short durations, on a scale of minutes, intermittently. HPWHs, on the other hand, heat water at a much slower rate and perform best with steady operation over long blocks of time, on a scale of hours. Unlike gas systems, a HPWH is unable to quickly recover storage tank heat after a prolonged hot-water draw. Recovery is sometime accomplished through electric resistance back up. A more efficient method to manage prolonged hot-water draw is to install additional hot water storage capacity. The heat pump can then slowly recover over several hours following the hot water draw.

HPWH systems with large storage capacity leads to additional benefits:

- Typically, lower first cost, because tanks are less expensive than heat pumps. A smaller heat pump capacity also reduces electrical service and infrastructure requirements for a building, further reducing first-cost impacts.
- Slightly larger tanks and heat pumps could enable grid flexibility by providing enough storage to disable the heat pumps during periods of peak

electric pricing. The slightly larger heat pumps could recharge the tanks more quickly during off-peak periods.

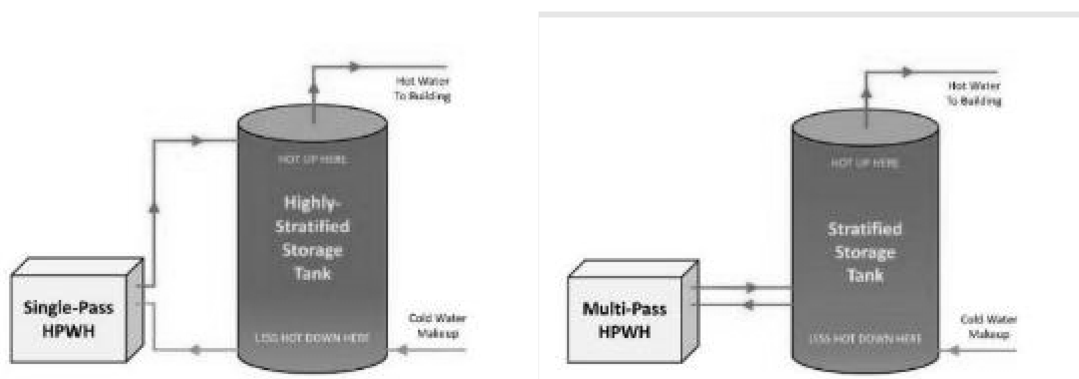
11.6.3.8 Single-Pass vs. Multi-Pass

A key design feature of a central HPWH system is whether it has a single-pass or multi-pass piping configuration. In a single-pass HPWH system, the cold water passes through the heat pump(s) once and is heated to the intended storage temperature. In this type of system, the heat pump draws cold water from the bottom of the storage tank and delivers hot water to the top of the storage tank, resulting in a highly stratified tank. HPWH equipment that use R744 require single-pass configuration, since R744 requires a large (20°F+) water temperature increase through the heat pump. Some R134 and R410A systems can have single-pass configurations.

In a multi-pass HPWH system, the cold water passes through the heat pump(s) multiple times, each time gaining a 7-10°F temperature increase, until the tank reaches the intended storage temperature. In a multi-pass system, the heat pumps draw cold water from the bottom third of the storage tank and deliver hot water to just above where it is drawn. This piping configuration can still produce a stratified tank, but less so than in a single-pass configuration. HPWH equipment that uses R410A, R134a, and refrigerants other than R744 can have multi-pass configuration, since they can handle a small water temperature lift through the heat pump. Some R134a and R410A systems can have either single-pass or multi-pass configuration.

Figure 11-61 shows schematic depictions of a single- vs. multi-pass systems side by side. Traditional gas water heaters are multi-pass systems.

Figure 11-61: Schematics of Single-Pass (left) vs. Multi-pass (right) HPWH Systems



Source: Ecotope

Some key differences between single-pass and multipass models are:

- Single-pass models have higher reported coefficient of performance (COP) values than multi-pass models.
- Most single-pass heat pumps do not operate well with warm incoming water temperatures (above approximately 110°F), while multi-pass systems performance does not degrade as much with warm incoming water

temperature. This is a critical feature that impacts DHW system configuration. DHW systems typically supply water at 120-125°F and return water at 105-115°F.

- For single-pass heat pumps, integration with recirculation systems is more complex and costly due to HPWH sensitivity to inlet water temperature. In contrast, multi-pass models integrated with the recirculation system resemble standard gas water heaters, which make multi-pass models more familiar albeit with a lower COP values.

Depending on the type of HPWH selected, designers must configure and control the plumbing system to ensure the HPWH operation stays in a favorable operation range. Section 11.7.3.40 describes current plumbing solutions, and most of them focus on single-pass HPWHs.

11.6.3.9 Spatial and Surrounding Air Temperature Considerations

Gas water heaters require nominal access to make-up air to support combustion. A small mechanical room or closet can suffice with no impact on performance. In situations with tight spatial limitations, makeup air can be vented directly to the gas unit through a small duct. In contrast, HPWHs pull thermal energy from the surrounding air and require constant ventilation and air circulation around the compressor unit. The heat pump cools the surrounding air, which must be replaced to avoid reducing system efficiency. Locating a heat pump indoors requires sufficient ventilation. With a split-heat pump configuration, the heat pump compressor units are commonly housed outdoors. These systems must be designed to operate at a range of ambient air temperatures and may not be suitable for colder climates. The ambient air temperature impacts system efficiency and capacity as it interacts with the refrigerant. Cold air temperatures can drastically reduce both efficiency and capacity, but high temperatures may also reduce performance. Section 11.7.3.40 describes suggested equipment locations for HPWH.

11.6.3.10 Inlet Water Temperature Impacts

Inlet water temperature from a municipal supply will fluctuate during the year. The coldest inlet temperatures occur during the winter. Cold inlet temperatures reduce performance for both gas boilers and heat pump water heaters, as it takes more heat to raise the inlet water to the designated storage temperature. However, the impact is more pronounced for HPWHs as interaction with the refrigerant can play a key role. Additionally, for HPWHs high inlet water temperatures can reduce efficiency depending on the refrigerant and heat exchanger configuration. Traditional plumbing configurations for gas water heater may significantly degrade HPWH performance.

11.6.3.11 Grid Flexibility and DR Capabilities

Unitary and central HPWH equipment with DR capabilities has the potential to meet a building’s water heating needs while also supporting electric grid needs. Grid flexibility refers to the ability of a device or equipment to control when and how it draws power from the grid based on building/occupant preferences, price signals, weather conditions, grid conditions, and other inputs. HPWHs convert electricity to thermal energy and can store this energy in system's storage tanks. This allows the system, with the right signals and controls, to respond to grid signals or utility programs.

11.6.3.12 Central HPWH Best Practices

This section provides best practices for central heat pump water heating system design. The best practices are intended to help with system design to meet code requirements and ensure optimal performance. Descriptions of applicable code requirements begin in Section 0.

11.6.3.13 HPWH Equipment and Storage Sizing and Equipment Selection

Hot water system sizing includes both the heating capacity and hot water storage volume needed to meet design day peak hot water demand. This is usually the day with coldest water inlet temperature in the winter. The American Society of Plumbing Engineers (ASPE) and ASHRAE developed existing common water heater sizing methodologies for central water heating equipment around gas water heater characteristics as these systems favor quick recovery capacity over large storage volume. The ASPE and ASHRAE sizing approaches can deliver reliable and cost-effective gas water heating systems, but sizing central HPWH systems with these sizing approaches may result in oversized HPWH equipment.

Unlike gas water heaters, which have linear and steady input and output performance, HPWH performance, operational characteristics, and design considerations vary largely depending on the refrigerant that the model uses and the heat exchanger configuration (i.e., single-pass vs. multi -pass). Designers must select equipment carefully to meet project needs.

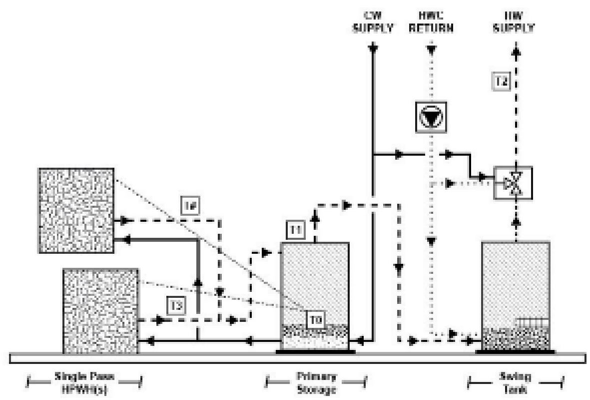
In general, sizing for central HPWHs should use large storage volumes to provide for peak hot water demand periods and smaller output capacity. This results in long, slow recovery periods with compressors operating up to 16-20 hours per day. These systems are likely more cost effective and efficient, and they have fewer maintenance issues compared to gas DHW systems.

11.6.3.14 System Plumbing and Configurations

For HPWHs, most single-pass heat pumps do not operate well with warm incoming water temperatures (above approximately 110°F). A critical design feature of CHPWH systems with hot water circulation systems is to separate the two distinct building DHW loads: 1) primary water heating and 2) temperature maintenance of recirculating hot water due to heat loss in the distribution loop. The HPWH(s) in the primary loop is referred as the primary HPWH. In separating the loads, the DHW system design can prioritize delivering cool water to the primary HPWHs for peak performance while maintaining thermal stratification in the primary tanks. Separating primary heating load and temperature maintenance load can improve equipment efficiency, lessen heating equipment cycling, and yield better system reliability.

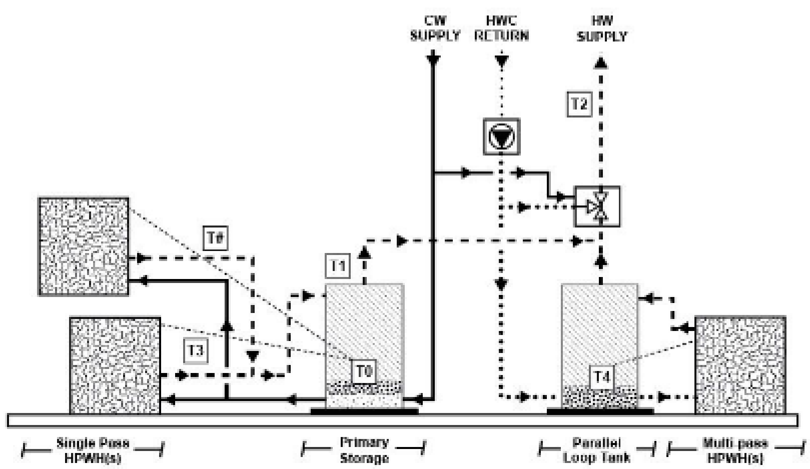
To separate the two loads, a key design practice is to use a temperature maintenance system separated from the thermally stratified primary storage volume. A temperature maintenance system consists of a recirculation pump, a storage tank (the loop tank), and a temperature maintenance heat source. A manufacturer developed two different types of temperature maintenance systems: 1) a swing tank design which uses a loop tank piped in series with the primary storage, illustrated in Figure 11-62, and 2) a parallel loop tank design which uses a loop tank piped in parallel with the primary storage, illustrated in Figure 11-63.

Figure 11-62: Single-Pass HPWH (s) with Swing Tank



Source: Ecotope

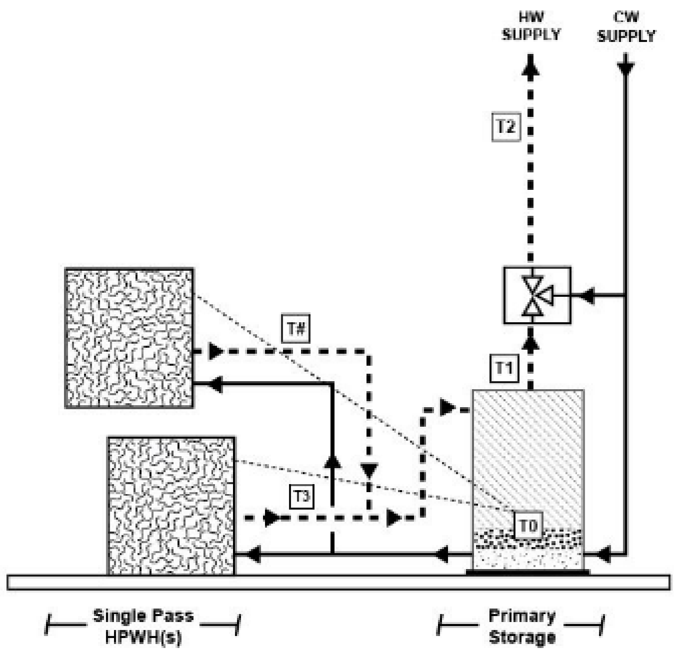
Figure 11-63: Single-Pass HPWH (s) with Parallel Loop Tank



Source: Ecotope

For a clustered design, the hot water heater(s) must be located close to each hot water usage such that a recirculation loop is not needed. This strategy is most easily applicable to buildings with up to three stories where the designer can locate the system on the roof and feed hot water to the dwelling units below with straight hot water piping, as shown in Figure 11-64.

Figure 11-64: Single-Pass HPWH(s) without Hot Water Recirculation (For Clustered Design)



Source: Ecotope

Central HPWH retrofits present more challenges than newly constructed buildings. Retrofit system designs may be limited by the design decision to re-use existing equipment such as the hot water storage tank or designating existing boiler or electric resistance heaters as back up. In comparison to newly constructed buildings, retrofit designs are often subject to tighter space constraints that negatively impact adequate equipment clearance and ventilation requirements.

11.6.3.15 Equipment Location

HPWHs need access to outdoor air or to a high volume of ventilation air as a heat source. Many existing gas-fired boilers are in small rooms in tight corners of buildings and vented as necessary to meet code. Tight spaces without adequate outdoor air and airflow may not provide adequate space for central and clustered HPWH equipment.

There are three typical locations for central HPWH equipment:

11.6.3.16 Outside

The most straightforward location for central HPWH equipment is outside, either on the roof or on the ground. All standalone HPWH units are rated for outdoor use. For ground-level installation, designers need to ensure the discharge air from the heat pump (which would be noticeably cold), is not directed at locations where people are likely to spend significant time, particularly in the winter. Equipment located outside or on a roof may present noise and/or vibration control concerns. As such, designers would need to consult manufacturer sound decibel ratings and implement appropriate noise/vibration control measures, particularly if equipment is located adjacent to living spaces.

- **Parking garage**: Ground floor or underground garages are another common location for central HPWH equipment. A covered, naturally ventilated garage is an ideal location for a HPWH, since it allows for adequate air circulation but remains protected from sun and rain. Fan-exhausted garages can also serve as locations for central HPWH; some designers have connected the heat pumps to the garage exhaust systems or use the heat pumps as the exhaust system. In colder climates, locating a HPWH in a garage, which will generally be slightly warmer than the outside air in the winter, can help raise the air temperature seen by the heat pump and improve system efficiency (Ecotope, 2009).
- **Inside with ducting**: In some circumstances, central HPWH equipment may need to be located inside or in areas with insufficient natural air circulation. These cases require ducted units. Manufacturers typically recommend ducting the (cold) exhaust air from the heat pumps out of the space and allowing makeup air into the room via passive louvers, though both air streams can generally be ducted if necessary. Designers must ensure louvers are large enough, and they must design the ducting to not exceed the static pressure limits of the heat pump fans.

11.6.3.17 Temperature Maintenance System

When a temperature maintenance system is used to separately handle the temperature maintenance load, designers must determine the recirculation loop heat loss to properly size the loop tank and determine whether a heater is needed. Managing temperature maintenance load is critical to reduce installed cost and improve operation efficiency. The most effective strategies to reduce heat loss of the distribution and recirculation piping are optimizing the piping design and insulating the piping.

When the temperature maintenance load is small, it can be handled using just a loop tank. Otherwise, a temperature maintenance heater maybe added. Designers should consider using a heater that can be configured to operate efficiently at higher incoming water temperature. Single-pass HPWH is not recommended due to poor performance when incoming water temperature is above 110°F.

11.6.3.18 Control

The primary HPWP(s) can be controlled to maintain a target output temperature between 120-140°F. Generating and storing the hot water at a higher temperature, normally above 135°F, can effectively increase the stored heating capacity of the plant, maximize load shifting capability and also to control possible legionella bacteria.

To prevent scalding, the high temperature hot water is tempered with recirculation water and/or incoming city water down to 120°F before delivery to the apartments.

When a loop tank is present, the high temperature hot water generated by the primary HPWH can be stored in the tank. The loop tank temperature setpoint must set to 120-125°F to only engage the less efficient loop tank heater when additional heat is needed.

Aquastats are temperature sensing devices used in water systems, synonymous to thermostats in non-hydronic systems. They have high- and low-temperature settings and control the ON/OFF status of the heating equipment (HPWHs in this case) as well as the circulator pump. Designers must carefully determine the aquastat location to avoid over cycling the HPWH. The general principal is to locate aquastat far enough away from incoming water to avoid triggering aquastat every time any water is used. If there are multiple primary storage tanks piped in series configuration, locating the aquastat in a second serial storage tank accomplishes this goal. The primary HPWHs can be set to switch ON when the aquastat in the middle storage tank drops below approximately 115°F, and to stay on until an aquastat in the first storage tank rises to approximately 100°F. Time delay built into HPWH operation can also help with avoiding turning on HPWH prematurely.

11.6.3.19 Electric Resistance as Backup and Supplemental Heat

Many storage-integrated heat pump units include both a heat pump and electric resistance backup for several reasons including:

- To reduce HPWH size and first cost when back up is only needed on the coldest days.
- To provide redundancy due to concern about HPWH reliability and long lead time for replacement parts.
- Some HPWH models cannot operate in low ambient temperature.

Low-temperature operation of R410A and R134a HPWH units allow operation down to 15-20°F and R744 central HPWH equipment that can operate well below 0°F. Properly sized and selected heat pumps should be able to eliminate the need for electric resistance backup in nearly all central HPWH applications in California climates.

In some cases, especially for retrofits, designers may be asked to reuse the existing gas-boiler or incorporate a new one as a backup system to the primary HPWH equipment. The existing boiler equipment would serve a similar, supplemental function to the HPWH as an electric resistance backup heater and provide additional capacity to handle low ambient conditions, meet extremely high hot water demand, or to ensure service continuity during maintenance events.

11.6.3.20 Design Resources and Tools

Many manufacturers offer support resources and tools to help designers with project scoping and high-level design concepts. These tools reference various rules-of-thumb and guidelines. Manufacturers are actively developing new and updated tools in this quickly evolving market.

To support the optimal HPWH sizing strategy that accounts for recovery speed differences, Ecotope developed Ecosizer, a generic sizing tool for central HPWH systems in multifamily buildings. Ecosizer provides basic water heater and storage sizing information for any piece of equipment with a known heating output capacity[5]. Ecotope developed the sizing method based on monitored hot water demand data from multifamily buildings. The tool yields smaller system size recommendations than the ASHRAE method tailored for gas water heating system.

11.6.3.21 Combined Hydronic System

Combined hydronic space heating systems use a single heat source to provide space and water heating. The modeling of these system types treats water heating performance separately from the space-heating function.

11.6.3.22 Drain Water Heat Recovery

This section describes drain water heat recovery equipment. It can be installed for compliance credit, except in instances where it is a prescriptive requirement. descriptions of applicable code requirements are in Sections 11.7.6 and 0.

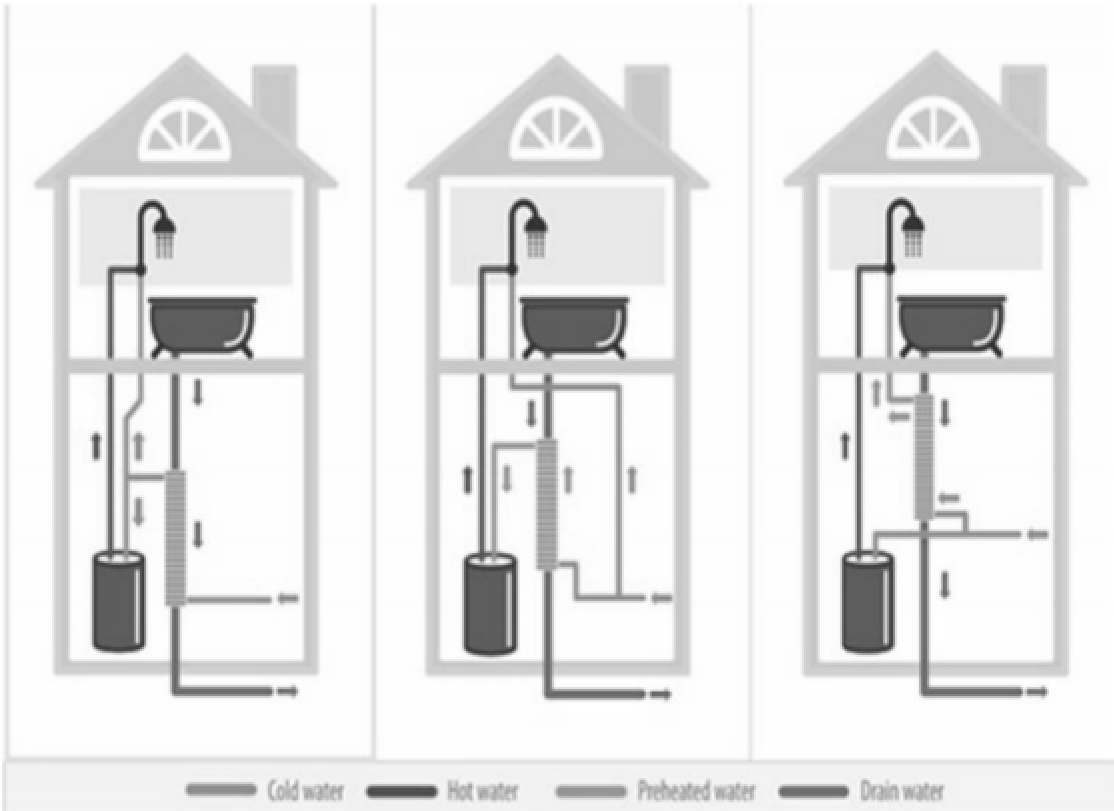
Drain water heat recovery (DWHR) is a technology that captures shower waste heat from the drain line. DWHR devices are counter flow heat exchangers, with cold water entering the building on one side of the device and hot drain water exiting the building on the other.

A DHWR device uses the reclaimed heat to preheat potable cold water that is then delivered either to the shower or the water heater. The device can be installed in either an *equal flow* configuration (with preheated water being routed to both the water heater and the shower) or an *unequal flow* configuration (preheated water directed to either the water heater or shower). Figure 11-65 schematically shows the three installation configurations. The energy harvested from a DWHR device is maximized in an equal flow configuration. They are available in both vertical design configurations, as shown in Figure 11-65, and in horizontal configurations. The two forms each have advantages and disadvantages, which should be evaluated for each potential installation.

To use these systems to comply with Energy Code, the design and installation must be HERS-verified and meet the Reference Appendix RA4.4.21 requirements for buildings with three stories or fewer and be field verified for buildings with four stories or more.

[5] https://ecosizer.ecotope.com/sizer/

Figure 11-65: The Three Plumbing Configurations of DWHR Installation (From left to right: Equal Flow, Unequal Flow - Water Heater, Unequal Flow - Fixture)



Source: Frontier Energy

11.6.3.23 DWHR Best Practices

DWHR are either distributed or central ganged systems based on the location of the DWHR devices and the number of drain water line(s) feeding into a DWHR device. DWHR devices on distributed designs are installed inline on shower drain stacks that are distributed throughout the building. Central banked designs have multiple DWHRs installed in parallel at a central location of the building and may be capable of recovering heat from all types of wastewater.

11.6.3.24 Distributed DWHR Design

Installation of DWHR devices in drain lines shared by multiple dwelling units is a common DWHR installation approach. This decentralized design creates a small loop, so the preheated cold water feeds either directly into the bath/shower cold water inlet (unequal flow to fixture) or to the main hot water plant (unequal flow to heater). Equal flow configurations are not common and could be cost prohibitive in multifamily applications, due to the distance between the DWHR device and the hot water plant.

One configuration is a heat recovery device at the base of each vertical plumbing stack to recover drain water waste heat from all dwelling units located on the second floor and above, as shown in Figure 11-66. This minimizes the impact on standard plumbing design and limits the length of additional piping that must be installed to accommodate a DWHR device.

For taller buildings where pressure zones are required every five to six stories, multiple DWHRs can be installed in one drain stack, one for each pressure zone such that the cold water preheated by a DWHR can be sent to each shower without needing a booster pump.

Figure 11-66: Distributed DWHR Installation with One DWHR Serving Two Dwelling Units
(From Left to Right: Unequal Flow – Heater, Unequal Flow – Fixture)

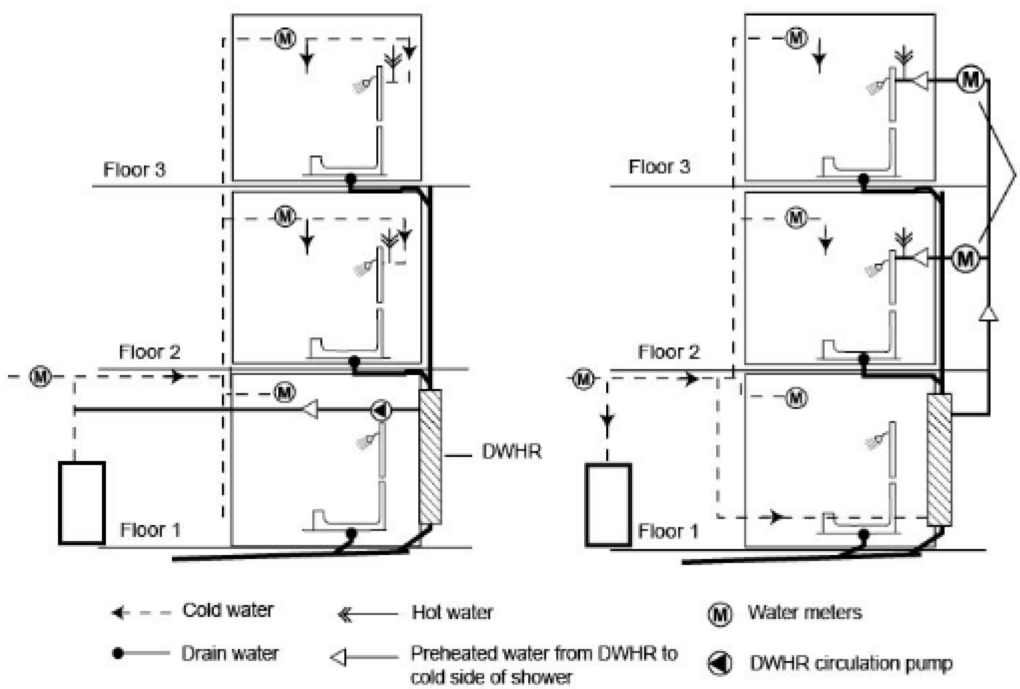


Figure 11-67: Single-Pass HPWH(s) without Hot Water Recirculation (For Clustered Design

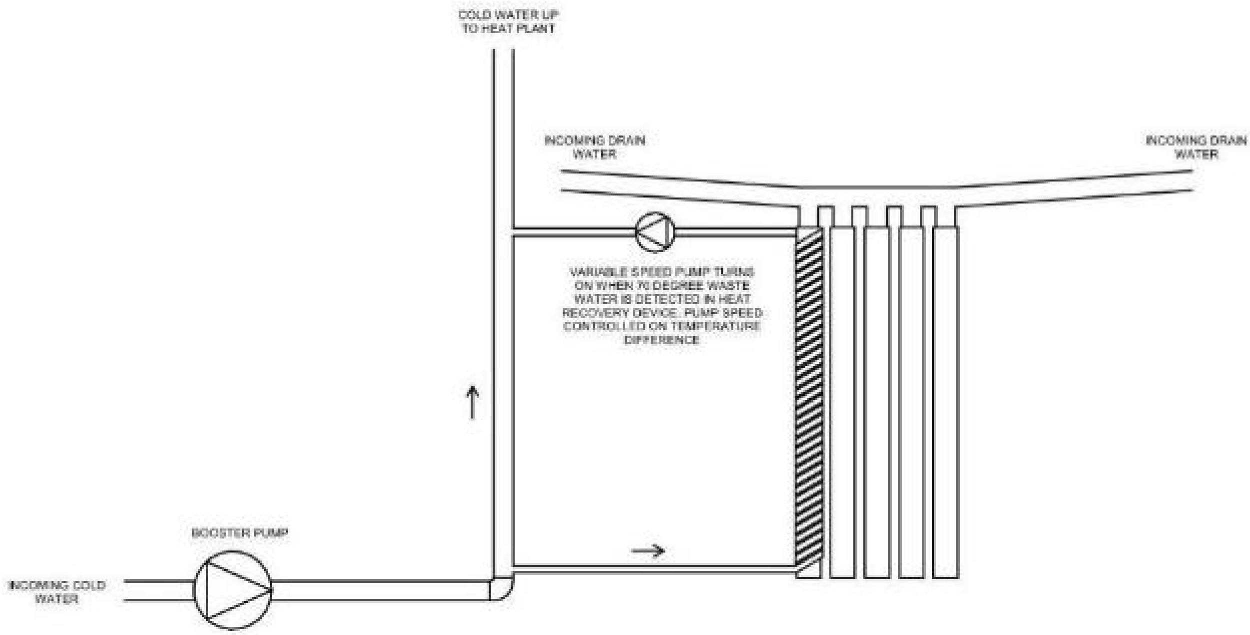
11.6.3.25 Central Ganged DWHR Design

Central ganged DWHR systems use multiple vertical drainage stacks to feed into a single large DWHR device (or manifold of multiple smaller devices) located in a ground floor mechanical room as illustrated in Figure 11-68. Individual drainage stacks are intentionally distributed throughout the building footprint; therefore, the routing between the base of the individual drain stack and the DWHR device is long.

The UPC Section 708.0 requires that horizontal drainage piping has a minimum slope of 0.25 inches per linear foot (IAPMO, 2019). In typical multifamily construction, there is 11 inches of vertical space between floor joists, which translates to an approximate maximum of 32 ft. of horizontal travel (assuming a two-inch pipe diameter and one inch of clearance for other construction considerations). In practice, the drainage stacks are not typically located close enough together such that all drain stacks could be gathered at a single central point to drain into a DWHR device. Therefore, a centralized DWHR system would require a detailed, custom plumbing design.

For central DWHR design, unequal flow to heater configuration is common as DWHRs are typically installed closer to the water heater and the long distance between the DWHRs and shower fixtures makes it impractical to send preheated water to shower.

Figure 11-68: Central DWHR Plant Schematic



Source: Ecotope

11.6.3.26 Impacts of Architectural Layout on DWHR Configurations

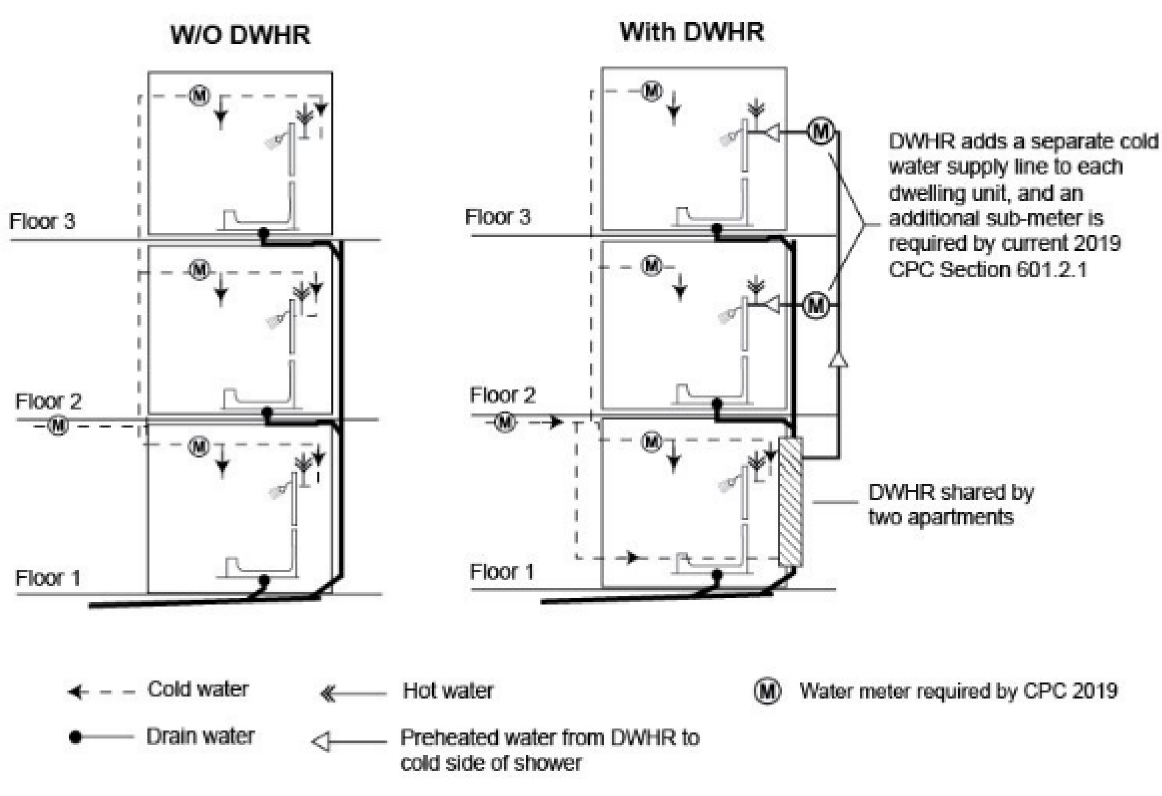
Due to sloping requirements in drain water piping and limited floor to floor height, drainpipes could have an approximate maximum of 32 ft. of horizontal travel. This means it is impractical to combine showers from the same floor if they are more than 32 ft. apart from each other. In typical multifamily design, the distance between two showers is usually more than 50 ft. If designers want to combine showers for one DWHR, they will need to locate showers closer to each other (e.g., using back-to-back showers). This is especially true for buildings with up to three stories where it is not possible to combine multiple showers located at different floor levels.

11.6.3.27 Impact of SB7 Water Meter Requirement on DWHR Configurations

Most current plumbing designs use dedicated cold and hot water risers for each fixture or washroom. SB7, which Governor Brown signed into law in 2016, directed the HCD to develop building codes that would require "the installation of water meters or water submeters in newly constructed multiunit residential structures and mixed-use residential and commercial facilities." HCD subsequently recommended code requirements for Section 601.2.1 of the CPC that the California Building Standards Commission approved for the 2019 CPC. The requirements in SB7 would require the submeters for market-rate dwelling units, but not for affordable housing.

To meet 2019 CPC Section 601.2.1 requirement, when a DWHR unit is installed in a drain line from multiple dwelling units to preheat cold water delivered to the shower or individual water heater, each dwelling unit would be required to have an additional dedicated water meter or submeter, as shown in Figure 11-69 below.

Figure 11-69: Water Metering Requirement with and Without DWHR



Source: Ecotope

11.6.3.28 Impacts of Drain Water Piping Design

Hot water is piped to most fixtures in multifamily buildings, including kitchen sinks, dishwashers, bathroom sinks (lavatories), bathtubs, showers, and clothes washing machines. Since DWHR is only effective when there are simultaneous hot water draws and drainage of that water, baths, and showers are typically the only fixtures where it makes sense to install DWHR. To concentrate the heat, a dedicated drain piping system is desirable, so only water from the bath/shower water is routed through the heat recovery device. This ensures that heat extraction occurs with the hottest drain water possible. Dedicated shower drain stack is consistent with current plumbing design practice.

Due to the potential long distance between the DWHR devices and shower fixtures, temperature loss in drainpipes may be an issue that impacts energy saving potential. There are two common drainpipe installation locations: 1) fur-out wall which has no insulation and 2) plumbing walls also serving as acoustic and fire separation wall, which are insulated. The second installation location has less temperature loss compared to the first location.

11.6.4 Multifamily Distribution Systems

This section describes various water heating distribution systems for multifamily buildings. Descriptions of applicable code requirements are in Section 11.7.6.2 and 11.7.7.2.

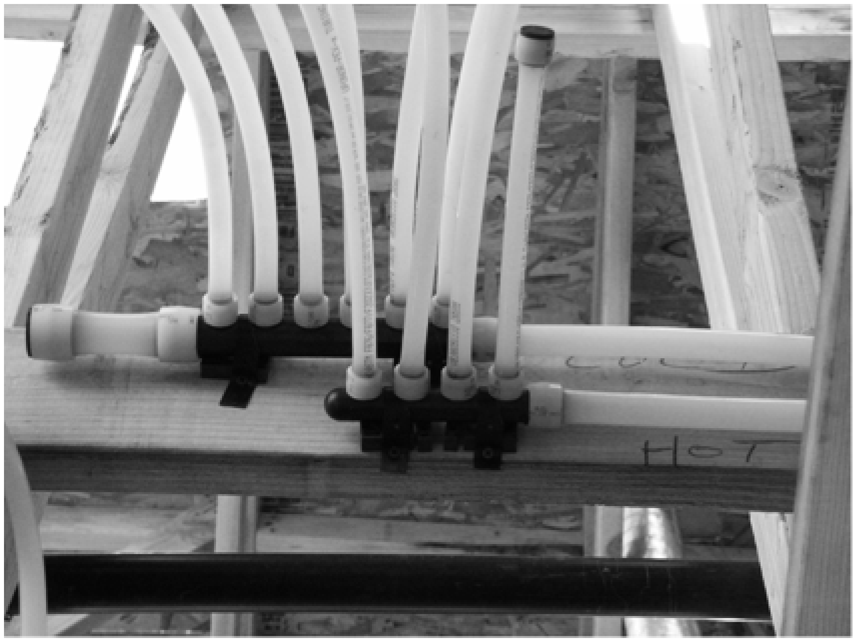
The water heating distribution system is the configuration of piping (and pumps and controls in the case of recirculating systems) that delivers hot water from the water heater to the end-use points within the building. By minimizing the length of distribution piping, energy use, water waste, wait time for hot water and construction costs can all be reduced. This section describes the types of distribution systems relevant to multifamily buildings, organized by system types applicable to hot water distribution *within* an individual dwelling unit and system types applicable to distribution network that serves multiple dwelling units.

11.6.4.1 Distribution System for an Individual Dwelling Unit

11.6.4.2 Trunk-and-Branch and Mini-manifold Configurations (Standard Distribution System)

The most basic plumbing layout assumed as the reference design in the performance approach, is represented by the conventional trunk-and-branch layout. This layout of a trunk-and-branch system may include one or more trunks, each serving a portion of the dwelling unit. The trunks are subdivided by branches that serve specific rooms, and they divide into twigs that serve a particular point of use. This distribution system type includes mini-manifold layouts, shown in Figure 11-70, which incorporate trunk lines that feed remote manifolds that then distribute water via twigs to the end-use points. A standard distribution system cannot incorporate a pump for hot water recirculation.

Figure 11-70: Mini-manifold Configuration



No pumps may be used to recirculate hot water with the standard distribution system. When designing a trunk-and-branch system, all segments should be as short and as small a diameter as possible. The requirements and guidelines for the installation of the standard distribution system are included in Reference Appendix RA3 - Residential Field Verification and Diagnostic Testing Protocols and RA4 - Eligibility Criteria for Energy Efficiency Measures.

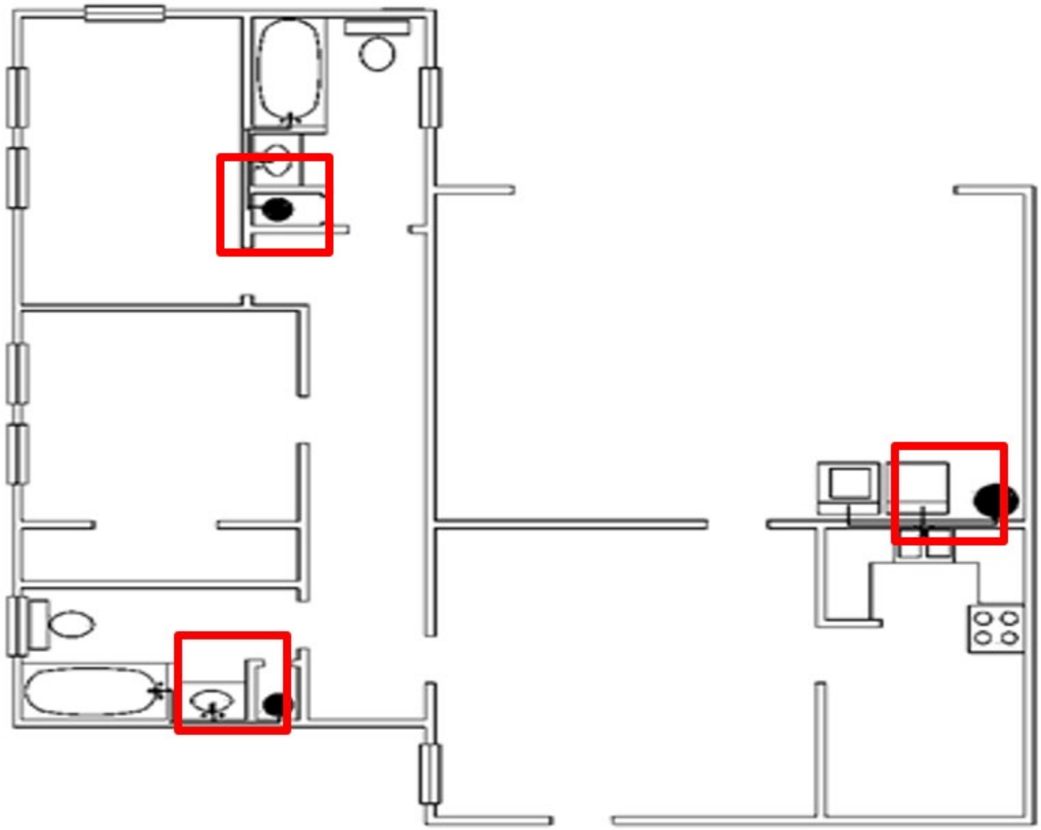
11.6.4.3 Central Parallel Piping System

The primary design concept in a central parallel piping system is an insulated main trunk line that runs from the water heater to one or more manifolds, which then feeds use points with ½" or smaller plastic piping. The traditional central system with a single manifold must have a maximum pipe run length of 15 ft. between the water heater and the manifold. Using mini-manifolds, the central parallel piping system can accommodate multiple mini-manifolds in lieu of the single central manifold, provided that 1) the sum of the piping length from the water heater to all the mini-manifolds is less than 15 ft. and 2) all piping downstream of the mini-manifolds is nominally ½ inch or smaller. The requirements for installation guidelines are included in RA3.

11.6.4.4 Point of Use

A *point-of-use distribution system design* significantly reduces the volume of water between the water heater and the hot water use points. Use of this type of system requires the water heater to be located adjacent to hot water use points, an indoor mechanical closet, or the use of multiple water heaters. Figure 11-71 provides an example of the latter approach where three water heaters are installed close to the use points.

Figure 11-71: Point-of-Use Distribution System



Source: 2019 CASE Report: Compact Hot Water Distribution

The distance between the water heater and any fixture using hot water cannot exceed the length specified in Table 11-51 below. The adopted requirements for installation guidelines are included in RA3 and RA4.

Table 11-51: Point-of-Use Distribution System

Size Nominal, Inch	Length of Pipe (ft.)
3/8"	15
1/2"	10
3/4"	5

11.6.4.5 Compact Hot Water Distribution System

The intent of a compact hot water distribution system design is to reduce the size of the plumbing layout by bringing the water heater closer to hot water use points than in typical trunk and branch systems. The Standards allow a basic credit and a HERS-verified compact hot water distribution system expanded credit.

Eligible compact hot water distribution designs can generate a compliance credit using the performance approach. There are two versions of the Compact Design credit. Basic Credit does not require HERS verification, while Expanded Credit requires field verification by a HERS Rater. Qualification for both credits is based on using a plan view, straight-line measurement to calculate a *Weighted Distance* to key hot water use points including the master bath, kitchen, and remaining furthest hot water fixture from the water heater (In some multifamily situations, there may not be another use point beyond the master bath and kitchen, resulting in the third term being ignored). If this resulting Weighted Distance is less than a Qualification Distance (dependent on floor area, number of stories in the dwelling unit, and number of water heaters), the plan is eligible for the Basic Credit. The Basic Credit does not require any further verification steps to secure the compliance credit. If the builder chooses to pursue an Expanded Credit, additional energy savings will be recognized under the performance method; however, there are several HERS-verification requirements that must be met.

H. *Weighted Distance Calculation Method*

Calculation of the Weighted Distance metric varies for a non-recirculating distribution system or a recirculation distribution system. The calculated Weighted Distance input cell would be activated in the compliance software if the user selected either the Basic CHWDS Credit or the Expanded Credit.

The basis of the calculation is a plan-view, straight-line measurement from the water heater to the center of the use point fixture in three rooms. It is calculated using the following equation.

Weighted Distance = x * d_MasterBath + y * d_Kitchen + z * d_FurthestThird

where,

x, y, and z = Weighted Distance coefficients (unitless), see Table 11-52.

d_MasterBath = The plan view, straight line distance from the water heater to the furthest fixture served by that water heater in the master bathroom (ft.).

d_Kitchen = The plan view, straight line distance from the water heater to the furthest fixture served by that water heater in the kitchen (ft.).

d_FurthestThird = The plan view, straight line distance from the water heater to the furthest fixture served by that water heater in the furthest room[6] (ft.).

Table 11-52 shows the values for the coefficients depending on the type of distribution system.

[6] Because the master bath and kitchen represent unique defined use points, the d_FurthestThird fixture must not be located in either of these rooms. The laundry room is excluded and should not be used as the furthest third room. In some multifamily cases, there may not be another qualifying use point, in which case the d_FurthestThird term equals zero.

Table 11-52: Weighted Distance Coefficients

Distribution System	x	y	z
Non-Recirculating	0.4	0.4	0.2
Recirculating	0.0	0.0	1.0

Note that the calculations are based on horizontal plan view distance measurements from the center of the water heater to the center of the use point in the designated location.

In dwelling units with multiple water heaters, the Weighted Distance "z term" calculation is performed for each water heater to arrive at a FurthestThird term averaged over each of the "n" water heaters installed. For a non-recirculating distribution system, the resulting Weighted Distance calculation would include the master bath, the kitchen, and an average of the FurthestThird term for each of the installed water heaters. (For recirculating systems, similarly the FurthestThird term would represent an average across the "n" water heaters.)

11.6.4.6 Recirculation System: Non-Demand Control Options

This type of distribution system encompasses all recirculation strategies that do not incorporate a demand control to minimize recirculating pump operation. Under this category, recirculation system types include uncontrolled continuous recirculation, timer control, temperature control, and time/temperature controls. Recirculation systems can save water, but the energy impact can be very high in a poorly designed and/or controlled system.

11.6.4.7 Recirculation System: Demand Control

A demand-control recirculation system uses brief pump operation in response to a hot water demand *signal* to circulate hot water through the recirculation loop. The system must have a temperature sensor, typically located at the most remote point of the recirculation loop. Some water heaters have temperature sensors located within the water heater. The sensor provides input to the controller to terminate pump operation when the sensed temperature rises. Typical control options include manual push button controls or occupancy sensor controls installed at key use areas (bathrooms and kitchen).

11.6.4.8 Distribution Systems Serving Multiple Dwelling Units

11.6.4.9 Central Demand Recirculation System (Standard Distribution System)

The standard distribution system for water heaters serving multiple dwelling units incorporates recirculation loops, which bring hot water to different parts of the building, and a demand control, which automatically shuts off the recirculation pump when the recirculation flow is not needed. Central recirculation systems include three components: recirculation loops, branch pipes, and pipes within dwelling units. Recirculation loops are used to bring hot water close to all dwelling units, but they are not expected to go through each dwelling unit. Branch pipes are used to connect pipes within dwelling units and the recirculation loops.

Demand controls for central recirculation systems are automatic control systems that control the recirculation pump operation based on measurement of hot water demand and hot water return temperatures.

11.6.4.10 Recirculation Temperature Modulation Control

A recirculation temperature modulation control must reduce the hot water supply temperature when hot water demand is determined to be low by the control system. The control system may use a fixed control schedule or a dynamic control schedule based on measurements of hot water demand. The daily hot water supply temperature reduction, which is defined as the sum of temperature reduction by the control in each hour within a 24-hour period, must be more than 50°F to qualify for the energy savings credit.

Recirculation systems must also meet the requirements of §110.3, covered in Section 11.7.5.

11.6.4.11 Recirculation Continuous Monitoring Systems

Systems that qualify as recirculation continuous monitoring systems for DHW systems serving multiple dwelling units must record no less frequently than hourly measurements of key system operation parameters, including hot water supply temperatures, hot water return temperatures, and status of gas valve relays for water-heating equipment. The continuous monitoring system must automatically alert building operators of abnormalities identified from monitoring results.

Recirculation systems must also meet the requirements of §110.3, covered in Section 11.7.5.

11.6.4.12 Non-recirculating Water Heater System

Multifamily buildings may use systems without a recirculation system if the dwelling units served are located so the branch pipes between the water-heating equipment and dwelling units are relatively short. This is the same as a *clustered design*.

11.6.5 Mandatory Requirements for Water Heating

This section describes code requirements applicable to all system types, and there are additional mandatory requirements specific to systems serving individual dwelling units described in Section 0.

11.6.5.1 Equipment Certification

§110.3(a)

Manufacturers must certify that their products comply with California's *Title 20 Appliance Efficiency Regulations*, Section 1605.1(f) at the time of manufacture.

Regulated equipment that applies to all the aforementioned system types in Section 5.2 must be listed in the California Energy Commission Appliance Efficiency Database.

For heat pump water heating systems serving multiple dwelling units…

11.6.5.2 Equipment Efficiency

§110.3(b), §110.1

Water heaters are regulated under California's *Title 20 Appliance Efficiency Regulations*, Section 1605.1(f). These regulations align with the federal efficiency standards for water heaters. Consumer water heaters and residential-duty commercial water heaters are both rated in Uniform Energy Factor (UEF). The draw pattern is based on the water heater's design first hour rating for storage water heater or gallons per minute (GPM) for instantaneous water heaters.

For commercial water heaters, unlike consumer water heaters, these water heaters are not rated in UEF. The required minimum energy efficiency for commercial water heaters is in terms of thermal efficiency and standby loss.

For heat pump water heaters used in central water heating system, there is no required minimum energy efficiency requirement. Manufacturers must certify their products to meet Joint Appendix 14 requirements.

11.6.5.3 Isolation Valves

§110.3(c)6

All newly installed instantaneous water heaters (minimum input of 6.8 kBTU/hr) must have isolation valves on both the incoming cold water supply and the hot water pipe leaving the water heater. Isolation valves assist in the flushing of the heat exchanger and help prolong the life of instantaneous water heaters. Instantaneous water heaters that have integrated drain ports for servicing are acceptable to meet the requirements of §110.3(c)6 and will not require additional isolation valves.

11.6.5.4 Pipe Insulation

§160.4(f)1

Table 11-53 summarizes the insulation requirements applicable to hot water piping in multifamily buildings. The insulation thickness requirements are specified in Table 160.4-A.

Table 11-53: Pipe Insulation Thickness Requirement*

Fluid Operating Temperature Range (°F)	Insulation Conductivity (in Btu·in/h·ft²·°F)	Insulation Conductivity Mean Rating Temperature (°F)	Units	< 1	1 to <1.5	1.5 to < 4	4 to < 8	8 and larger
Above 350	0.32-0.34	250	Inches**	4.5	5.0	5.0	5.0	5.0
Above 350	0.32-0.34	250	R-value***	R 37	R 41	R 37	R 27	R 23
251-350	0.29-0.32	200	Inches**	3.0	4.0	4.5	4.5	4.5
251-350	0.29-0.32	200	R-value***	R 24	R 34	R 35	R 26	R 22
201-250	0.27-0.30	150	Inches**	2.5	2.5	2.5	3.0	3.0
201-250	0.27-0.30	150	R-value***	R 21	R 20	R 17.5	R 17	R 14.5
141-200	0.25-0.29	125	Inches**	1.5	1.5	2.0	2.0	2.0
141-200	0.25-0.29	125	R-value***	R 11.5	R 11	R 14	R 11	R 10
105-140	0.22-0.28	100	Inches**	1.0	1.5	2.0	2.0	2.0
105-140	0.22-0.28	100	R-value***	R 7.7	R 12.5	R 16	R 12.5	R 11

Source: excerpt from Table 160.4-A of the Energy Code

* Space heating and Service Water Heating Systems (Steam, Steam Condensate, Refrigerant, Space Heating, Service Hot Water)

**Minimum Pipe Insulation Required (Thickness in inches or R-value)

*** Nominal Pipe Diameter (in inches)

Piping exempt from mandatory insulation Includes:

- Factory-installed piping within space conditioning equipment.
- Piping that penetrates framing members. This piping is not required to have insulation where it penetrates the framing. However, if the framing is metal, then some insulating material must prevent contact between the pipe and the metal framing.
- Piping located within exterior walls that are installed so that piping is placed inside wall insulation. Wall insulation may be an acceptable alternative insulation method for sections of pipes that would otherwise need pipe insulation, if the wall insulation in the walls where the pipes are located meets the requirements of QII and the pipes are roughly centered in the wall cavity (See Reference Appendix RA4.4.1).
- Piping that are surrounded with at least one inch of wall insulation, two inches of crawlspace insulation, or in the attic continuously buried by at least four inches of

blown-in ceiling insulation. Piping may not be placed directly in contact with sheetrock and then covered with insulation to meet this requirement.

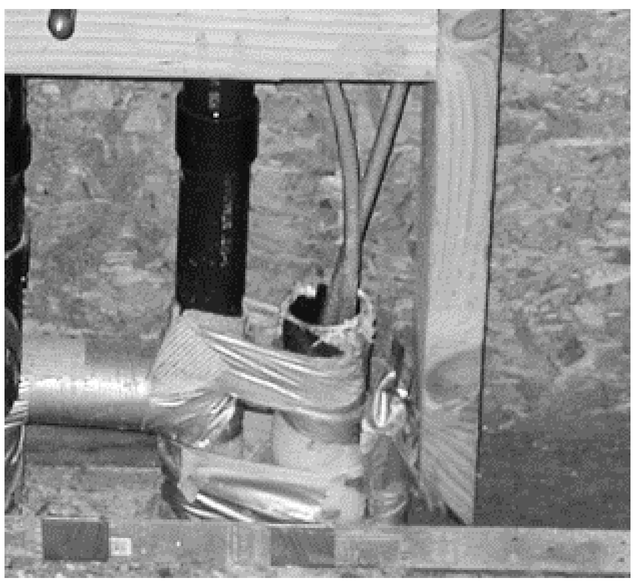
11.6.5.5 Insulation Protection

§160.4(f)2

If hot water piping insulation is exposed to weather, it must be protected from physical damage, ultraviolet light deterioration, and moisture. Insulation is typically protected by aluminum, sheet metal, painted canvas, plastic cover, or a water-retardant coating that shields from solar radiation. Adhesive tape should not be used as insulation cover because removal of the tape will damage the integrity of the original insulation during preventive maintenance.

All DHW pipes that are buried below grade must be installed in a waterproof and non-crushable casing or sleeve. The installation shown in Figure 11-72 below would not meet the installation requirements since it is not insulated. In addition, in Figure 11-72 the hot and cold water lines are not separated. Heat transfer will occur, resulting in energy loss and causing condensation on the cold water line.

Figure 11-72: Noncompliant Below-Grade Piping and Hot and Cold Water Lines Separation



11.6.6 Systems Serving Individual Dwelling Units

This section describes requirements applicable to water heating systems serving individual dwelling units and common use area without a recirculation loop. These requirements are in addition to requirements in Section 11.7.5.

11.6.6.1 Individual Dwelling Unit Water Heating Equipment

11.6.6.2 Mandatory Requirements

§160.4(a)

Electric readiness is required if a gas or propane water heater is installed. These requirements include installing a dedicated 125-volt (V) electrical receptable, reserving space for single pole circuit breaker and having a condense drain. Refer to Section **Error! Reference source not found.** for detailed descriptions.

11.6.6.3 Prescriptive Requirements

§170.2(d)1

There are three options to comply with the prescriptive requirements for water heating systems serving individual dwelling units in newly constructed multifamily buildings:

- **Option 1:** Install a single, 240 volt heat pump water heater. In addition, the building must comply with both of the following as applicable:
  - For Climate Zones 1 and 16, a compact hot water distribution design meeting the requirements specified in the Reference Appendix RA 4.4.6.
  - For Climate Zone 16 only, a DWHR system meeting the requirement specified in the Reference Appendix RA 3.6.9.

  Option 2: Install a single HPWH that meets the requirements of NEEA Advanced Water Heater Specification Tier 3 or higher. In addition, for Climate Zone 16 only, a drain water heat recovery system meeting the requirement specified in the Reference Appendix RA 3.6.9. The list of qualified product list of NEEA HPWH can be found here:www.neea.org/img/documents/qualified-products-list.pdf
- **Option 3:** Install one or more natural gas or propane instantaneous water heater with an input rating of 200,000 BTU per hour or less and no storage tank.

11.6.6.4 Performance Approach

For individual water heating systems serving individual dwelling units, any type or number of water heaters supported by the software can be installed. The calculated energy use of the proposed design is compared to the standard design energy budget, based on either a single gas instantaneous water heater for gas water heaters with a standard distribution system or a HPWH with compact distribution system and DWHR, where applicable.

Joint Appendix (JA) 13 provides qualification requirements for HPWH demand management systems. Qualifying HPWHs have the capability to optimize operation to reduce normal water heater operation during on-peak periods by biasing operation prior to the peak period. Future opportunities include overheating the storage tank above setpoint prior to the peak period, further improving the electrical load profile of these systems. A credit exists for these HPWHs within the compliance software. JA13 certified HPWHs, which must have a mixing valve installed to prevent any scalding risks, are currently listed at this website:

www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment/ja13

11.6.6.5 Individual Dwelling Unit Distribution System

This section describes requirements for distribution systems serving individually dwelling units. These requirements are distinct from requirements applicable to systems serving multiple dwelling units.

There are no additional mandatory requirements specific to equipment serving individual dwelling units other than those described in Section 11.7.5.

11.6.6.6 Prescriptive Requirements

§170.2(d)

Installation of a demand recirculation control to minimize pump operation and heat loss from pipes is a prescriptive requirement. This is applicable regardless of fuel source.

11.6.6.7 Performance Approach

The compliance software does not include a hot water recirculation pump for the standard distribution system serving a single dwelling unit and does not allow credit for any additional DHW design features.

Alternative distribution systems are compared to the standard design by using distribution system multipliers, which effectively rate alternative options. Table 11-54 lists all the recognized distribution systems that can be used in the performance approach with the assigned distribution multiplier. The standard distribution system has a multiplier of 1.0. Distribution systems with a multiplier less than 1.0 represent an energy credit, while distribution systems with a multiplier greater than 1.0 are an energy penalty. For example, pipe insulation with HERS inspection required (PIC-H) has a multiplier of 0.8. That means that it is modeled at 20% less distribution loss than the standard distribution system.

Table 11-54: Applicability of Distribution Systems Options Within a Dwelling Unit

Distribution System Types	Assigned Distribution System Multiplier	Systems Serving a Single Dwelling Unit
No HERS Inspection Required		
Trunk and Branch -Standard (STD)	1.0	Yes
Parallel Piping (PP)	1.1	Yes
Point of Use (POU)	0.3	Yes
Recirculation: Non-Demand Control Options (R-ND)	9.8	Yes
Recirculation with Manual Demand Control (R-Dmn)	1.75	Yes
Recirculation with Motion Sensor Demand Control (R-DAuto)	2.6	Yes
HERS Inspection Required		
Pipe Insulation (PIC-H)	0.85	Yes
Parallel Piping with 5’ maximum length (PP-H)	1	Yes
Recirculation with Manual Demand Control (R-DRmc-H)	1.6	Yes
Recirculation with Sensor Demand Control (RDRsc-H)	2.4	Yes

Source: California Energy Commission

11.6.7 Systems Serving Multiple Dwelling Units

This section describes requirements applicable to water heating systems serving multiple dwelling units and common use areas with a recirculation loop. These requirements are in addition to requirements captured in Section 11.7.5.

11.6.7.1 Multiple Dwelling Unit Water Heating Equipment

There are no additional mandatory requirements specific to equipment serving multiple dwelling units other than those described in Section 11.7.5.

11.6.7.2 Prescriptive Requirements

§170.2(d)

There are three options for using the prescriptive approach for systems serving multiple dwelling units for newly constructed multifamily buildings:

1. A central HPWH system
2. A central gas or propane-fired water heater or boiler with minimal solar waving fraction based on the Climate Zone
3. A water-heating system determined by the Executive Director to use no more energy than the central HPWH and central gas or propane-fired systems

The water heater must have an efficiency that meets the requirements in §110.1 and §110.3. In addition, if a central recirculation system is installed, it must be installed with demand recirculation.

A. Central Heat Pump Water Heating Systems

§170.2(d)2

To use the prescriptive approach, the central HPWH system design must use a temperature maintenance system to meet the DHW temperature maintenance load. A temperature maintenance system consists of a recirculation pump, a *loop tank*, and a temperature maintenance heat source. The hot water return from the recirculation loop must connect to the loop tank and cannot connect directly to the primary storage tanks or the inlet of the primary HPWH equipment. This design approach can prioritize delivering cool water to the HPWHs for peak performance while maintaining thermal stratification in the primary tanks.

The prescriptive approach allows the use of either single-pass or multi-pass HPWH as the primary heat source. It does not allow the use of a HPWH configured as single-pass operation to handle temperature maintenance load. The temperature maintenance heater must use electricity as the fuel source. Multi-pass HPHW or electric resistance water heaters are both acceptable in the temperature maintenance system.

When there are multiple primary storage tanks included in the design, the primary storage tanks must be piped in series when the primary HPWH is configured as single-pass operation. This configuration can maximize hot water storage capacity, minimize disruption of stratification by cold city water, and allow the cool temperature water to connect to the HPWP inlet. In addition, piping the primary tanks in series allows the strategic placement of Aquastat for HPWH control to improve overall operation efficiency and avoid over cycling. On the other hand, when the primary HPWH is configured as a multi-pass system, the primary storge tanks mush be configured in parrel to ensure proper operation.

To effectively increase storage capacity and leverage the load shifting capability of hot water storage, the prescriptive approach requires the primary hot water storage temperature must be at least 135°F. In addition, the loop tank temperature setpoint must be controlled to be at least 10°F lower than the primary thermal storage tank setpoint. Since the loop tank heater, which could be an electric resistance heater or a multi-pass HPWH, operate less efficiently than the primary HPWH, lowered loop tank setpoint can ensure to only engage the loop heater when additional heat is needed for temperature maintenance purpose.

HPWH compressor must be able to operate to meet all control requirements stated above when the ambient air temperature is equal to or higher than 40°F.

In addition to the plumbing configuration and control requirements, the prescriptive approach requires presentation of specified information in the design documentation. JA 14. 4 specifies the following information must be included:

- Minimum and maximum ambient air temperature designed for the HPWH to operate. HPWH performance is impacted by the ambient air conditions. Designers must consider the climate conditions and where to locate the HPWHs for equipment selection.
- Minimum and maximum cold-water temperature.
- Minimum and maximum building demand at design draw and recovery conditions and duration. Designers must consider these parameters to properly size for HPWH and storage tank, regardless of if load shifting is considered.
- Recirculation loop heat loss: designers must determine the recirculation loop heat loss to properly size the loop tank and determine whether a heater is needed.

Recirculation system is not required for a central HPWH system serving eight or fewer dwelling units. When recirculation system is present, it must meet all applicable requirements in the Energy Standard.

B. Gas or Propane Water Heating Systems with Solar Savings Fraction

To use the prescriptive path with gas or propane central water heating system, water heaters with input capacity at or over 1 MMBtu/h must have a minimum thermal efficiency of 90%. Water heaters with lower capacity rate are exempt from the thermal efficiency requirement. Additional exemption is allowed when 25% or more of the annual water heating load is met by on-site solar PV system or site-recovered energy.

When a central gas or propane water heating system is installed, a solar water heating system with a minimum solar fraction is also required. The minimum solar savings fraction requirement is climate zone dependent; the minimum is 0.2 for Climate Zones 1 through 9 and 0.35 in Climate Zones 10 through 16. If a DWHR device meeting the requirements specified in the Reference Appendix RA 3.6.9 is installed, moderately lower solar savings fraction levels are required instead. The minimums become 0.15 for Climate Zones 1 through 9 and 0.30 for Climate Zones 10 through 16.

The water heating calculation method allows water heating credits for solar water heaters. Solar thermal systems save energy by using renewable resources to offset the use of conventional energy sources. For multifamily buildings, only systems with OG-100 collectors can be installed. For detailed instructions on installation of solar water heaters, refer to Reference Appendix RA4.4.20.

The database of SRCC-certified equipment is on the SRCC website at the following link:

www.secure.solar-rating.org//Certification/Ratings/RatingsSummaryPage.aspx?type=1

The database of IAPMO R&T-certified equipment is on the IAPMO R&T website at the following link:

www.iapmort.org/Pages/SolarCertification.aspx

11.6.7.3 Performance Approach

C. Central Heat Pump Water Heating System

Joint Appendix 14 Qualification Requirements for Central Heat Pump Water Heater Systems sets the requirements for central HPWH system using the performance approach. The requirements are applicable to systems to be installed in multifamily buildings and nonresidential buildings.

JA 14.3 requires that central HPWH equipment to be certified to the Energy Commission, which includes submitting required performance data to the Commission. The process of data submission can be found in the link below:

www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment-8

Each basic model that is claimed on the performance certificate of compliance must be certified. Manufacturers must determine performance data for each basic model, which means all units of a given type of product manufactured by one manufacturer; have the same primary energy sources; and have essentially identical electrical, physical, and functional (hydraulic) characteristics that affect energy consumption, energy efficiency, water consumption, or water efficiency.

JA 14.3 further details the acceptable methods to determine performance data and the data reporting requirement:

- When simulation is used, an alternative efficiency determination methods (AEDM) as described in 10 CFR part 429.70(a)-(c) must be used to generate performance data required in JA 14.3.2

- When lab testing is used, testing must be conducted as described in Appendix E to Subpart G of 10 CFR Part 431 for each of the test conditions described in JA14.3.3.

JA 14.4 Design Condition Documentation Requirements are applicable for central HPWH designs using prescriptive and performance approach.

When the proposed DHW system is a central DHW system that uses electricity as the primary fuel source, the standard design is a central HPWH system that is based on the prescriptive requirement of a central HPWH in Section 170.2(d)2The standard design central HPWH system has a recirculation system with single pass compressors, with separate primary storage tank and recirculation loop storage tank.

(Place holder to describe standard Central HPWH design)

JA 13 provides qualification requirements for HPWH demand management systems. Qualifying HPWHs have the capability to optimize operation to reduce normal water heater operation during on-peak periods by biasing operation prior to the peak period. Future opportunities include overheating the storage tank above setpoint prior to the peak period, further improving the electrical load profile of these systems. A credit exists for these HPWHs within the compliance software. JA13 certified HPWHs, which must have a mixing valve installed to prevent any scalding risks, are currently listed at this website:

www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment/ja13

D. Solar Water Heating

Solar water heating systems with a solar fraction higher than the specified prescriptive minimum can be used as a tradeoff under the performance approach. Users now input collector and system component specifications to calculate a corresponding solar fraction for the proposed system.

11.6.7.4 Distribution Systems Serving Multiple Dwelling Units

This section describes requirements for distribution systems serving multiple dwelling units. These requirements are distinct from requirements applicable to systems serving individual dwelling units.

11.6.7.5 Mandatory Requirements

§110.3(c)4

Multifamily buildings recirculation loop consists of a supply portion of larger diameter pipe connected to smaller diameter branches that serve multiple dwelling units, guest rooms, or common use area fixtures and a return portion that completes the loop back to the water heating equipment. The large volume of water that is recirculated during periods of high use creates situations that require the installation of certain controls and servicing mechanisms to optimize performance and allow for lower cost of maintenance. This section covers the mandatory requirements for system serving multiple dwelling units and with recirculation loops.

E. Air Release Valves

§110.3(c)4A

The constant supply of new water in combination with the continuous operation of pumps creates the possibility of the pump cavitation due to the presence of air in the water. *Cavitation* is the formation of bubbles in the low-pressure liquid on the suction side of the pump. The cavities or bubbles will collapse when they pass into the higher regions of pressure, causing noise and vibration that may lead to damage to many of the components. In addition, there is a loss in capacity, and the pump can no longer build the same head (pressure). This ultimately affects the efficiency and life expectancy of the pump.

Cavitation must be minimized either by installing an air release valve or mounting the pump vertically. The air release valve must be located no more than four ft. from the inlet of the pump. The air release valve must also be mounted on a vertical riser with a length of at least 12 inches.

F. Backflow Prevention

§110.3(c)4B

Temperature and pressure differences in the water throughout a recirculation system can create backflows. This can result in cooler water from the bottom of the water heater tank and water near the end of the recirculation loop flowing backward toward the hot water load and reducing the delivered water temperature.

To prevent this from occurring, the Energy Code require that a check valve or similar device be located between the recirculation pump and the water heating equipment.

G. Equipment for Pump Priming/Pump Isolation Valves

§110.3(c)4C&D

Repair labor costs can be reduced significantly by planning and designing for pump replacement when the pump fails. Provision for pump priming and pump isolation valves helps reduce maintenance costs.

To meet the pump priming equipment requirement, a hose bib must be installed between the pump and the water heater. In addition, an isolation valve must be installed between the hose bib and the water heating equipment. This configuration will allow the flow from the water heater to be shut off, allowing the hose bib to be used for bleeding air out of the pump after pump replacement.

The requirement for the pump isolation valves will allow replacement of the pump without draining a large portion of the system. The isolation valves must be installed on both sides of the pump. These valves may be part of the flange that attaches the pump to the pipe. One of the isolation valves may be the same isolation valve as for pump priming.

H. Connection of Recirculation Lines

§110.3(c)4E

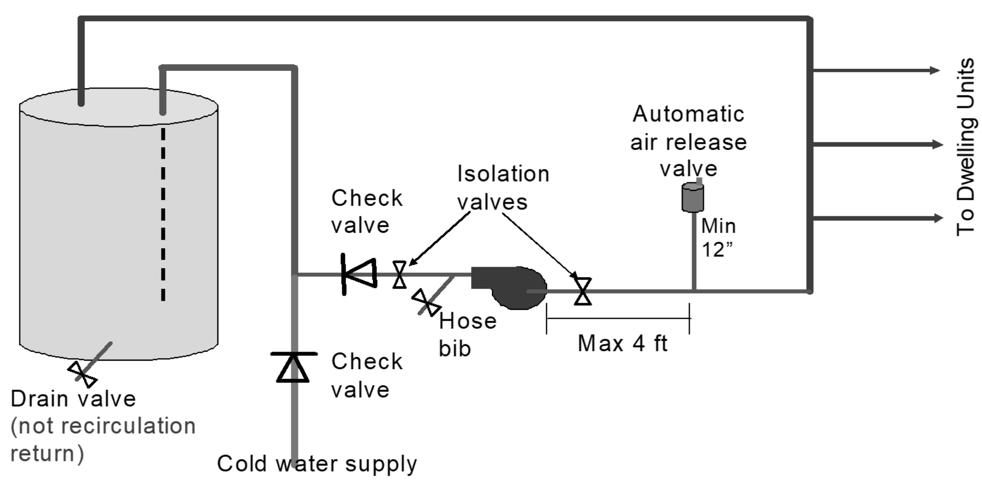
Manufacturer's specifications should always be followed to assure optimal performance of the system. The cold water piping and the recirculation loop piping should never be connected to the hot water storage tank drain port.

I. Backflow Prevention in Cold Water Supply

§110.3(c)4F

The dynamic between the water in the heater and the cold water supply are similar to those in the recirculation loop. Thermosyphoning can occur on this side of this loop, just as it does on the recirculation side of the system. To prevent this, the Energy Code require a check valve to be installed on the cold water supply line. The valve should be located between the hot water system and the next closest tee on the cold water supply line. The system must comply with the expansion tank requirements as described in the California Plumbing Code.

Figure 11-73: Mandatory Central Recirculation System Installation Requirements



Source: California Energy Commission

11.6.7.6 Prescriptive Requirements

§170.2(d)

Installation of an automatic recirculation control based on sensing hot water demand and recirculation return temperatures is a prescriptive requirement. This is applicable regardless of system type or fuel source.

11.6.7.7 Performance Approach

For systems serving multiple dwelling units with a recirculating pump, the standard distribution system design is based on a central recirculation system automatically controlled by sensing of hot water demand and recirculation return temperatures. Systems designed with other options are allowed, and some of them are subject to HERS field verification.

Buildings with uncontrolled recirculation systems will need to install other efficiency features to offset the resulting compliance penalty. Table 11-55 lists all the recognized distribution systems that can be used in the performance approach with the assigned distribution multiplier.

Table 11-55: Applicability of Distribution Systems Options Serving Multiple Dwelling Units

Distribution System Types	Assigned Distribution System Multiplier	Central Recirculation Systems Serving Multiple Dwelling Units
No HERS Inspection Required		
Trunk and Branch -Standard (STD)	1.0	Yes
HERS Inspection Required		
Pipe Insulation (PIC-H)	0.85	Yes

J. Dual-Loop Recirculation System

Dual-loop recirculation systems are a performance option. In a dual loop recirculation system, each recirculation branch loop serves roughly half of the dwelling units. Pipe diameters can be downsized in a dual loop system compared to a single-loop system serving all dwelling units while still following California Plumbing Code requirements. The total pipe surface area is effectively reduced with smaller distribution pipe diameters, even though total pipe length remains similar to than that of a single-loop system.

For example, for simple building footprints, locating the water heating equipment at the center of the building footprint rather than at one end of the building helps minimize the pipe length. If a water heating system serves several building sections, the water heating equipment would preferably nest between these sections.

11.6.8 Mandatory Requirements for Residential Swimming Pool and Spa Heating

The Energy Code include several mandatory requirements for residential swimming pool filtration equipment, which affect pump selection and flow rate, piping and fittings, and filter selection. These standards are designed to reduce the energy used to filter and maintain the clarity and sanitation of pool water. Refer to Section 4.7 on Pool and Spa Heating Systems for details.

11.6.9 Additions and Alterations

§180.0

Additions and alterations to existing individual water heating systems are subject to mandatory requirements and select prescriptive requirements. These requirements apply to systems serving multiple dwelling units. Examples of instances that trigger requirements include:

- Increasing the number of water heaters serving individual dwelling units (as part of an addition).
- Replacing the existing water heating or adding water heaters and/or adding hot water piping.
- Replacing a heating element in a water heat but not replacing the entire water heater.

11.6.9.1 Mandatory and Prescriptive

§180.1(a)3, §180.2(b)3, §160.4(f)Water heater systems that serve one or more dwelling units as part of an addition will meet the prescriptive requirements specified in §170.2(d) on both water heater and distribution system.

Altered or replaced water heating systems or components serving dwelling units must meet mandatory pipe insulation and insulation protection requirements. Reference Section 11.7.5 for more details.

For a replacement water heater, there are separate requirements for the distribution system and the water heater. The requirements for pipe insulation are mandatory and cannot be traded off. For the distribution system and the water heater, if the prescriptive requirements cannot be met, then the performance approach can be used to comply.

To meet the prescriptive requirements, the replacement water heater must be one of the following:

- A natural gas or propane water heater.
- If the existing water heater is an electric resistance water heater, a replacement electric water heater may be installed.
- A single HPWH meeting NEEA Tier 3 or higher specifications.

- A single heat pump water heater, 1) located in an unconditioned space like the garage or in conditioned space, 2) placed on an incompressible (rigid) surface that is insulated to a minimum R-10, and 3) installed with a communication interface (demand control device) meeting §110.12(a) or an ANSI/CTA-2045-B communication port.
- A water-heating system determined by the California Energy Commission's Executive Director to use no more energy than those specified above.

If a recirculation system is installed, then it must be a demand recirculation system with a manual on/off control to meet the prescriptive requirements.

11.6.9.2 Performance Approach

§180.1(b), 180.2(c)

Modeling an addition alone requires meeting the same requirements as newly constructed buildings. The prescriptive requirements apply only to the space that is added, not the entire building

For altered or replaced water heating systems, the calculated energy use of the proposed design is compared to the standard design energy budget. For system serving individual dwelling units, the standard design is based on either a single gas instantaneous water heater for gas water heaters or a HPWH system with a standard distribution system. For systems serving multiple dwelling units, the standard design is based on the existing efficiency level.

11.6.10 Compliance and Enforcement

Chapter 2 of this compliance manual addresses the compliance and enforcement process, and it discusses the roles and responsibilities of each of the major parties, the compliance forms, and the process for field verification and/or diagnostic testing. This section highlights compliance enforcement issues for water heating systems.

11.6.10.1 Design Review

The design review verifies that the certificate of compliance matches the plans and specifications for the proposed building. The certificate of compliance has a section where special features are listed. The following are water heating features that should be listed in this section of the certificate of compliance:

- Any system type other than one water heater per dwelling unit
- Non-NAECA large water heater performance
- Indirect water heater performance
- Instantaneous gas water heater performance
- Distribution system type and controls
- Solar system

- Combined hydronic system
- Central HPWH system

Information provided on the certificate of compliance must be included on the plan set. Highlighting key concerns or adding notes will allow field inspectors to quickly catch any features that should be installed that made a significant difference in compliance.

When a central heat pump water heating system is installed, design documentation should include additional information required in JA 14.4, including equipment design air and outlet temperature ranges, building demand, and recirculation loop heat loss.

11.6.10.2 Field Inspection

During construction, the contractor (or the specialty contractors or both) completes the necessary sections of the Certificate of Installation. There is one section of the Certificate of Installation where information about the installed water heating system is entered if complying prescriptively with a gas instantaneous, select gas storage above 55 gallons, or a NEEA Tier-3 rated heat pump water heating equipment. Additional documents are needed to comply prescriptively for all other options. (See Appendix A.)

Inspectors should check that the number and types of water heating systems indicated on the installation certificates match the approved certificate of compliance. For a central heat pump water heater, inspectors should check that plumbing configurations between the water heater, storage tanks, and recirculation loop correspond to plan specifications.

11.6.10.3 HERS Field Verification and/or Diagnostic Testing

11.6.10.4 Individual Dwelling Unit Water Heaters

HERS verification is required for all hot water distribution types that include options for field verification. The first type is alternative designs to conventional distribution systems that include parallel piping, demand recirculation, and automatic and manual on-demand recirculation. The second type is for compact distribution systems earning the expanded credit, which can be used only when verified by field verification. Where HERS verification is required, the HERS Rater must verify that the eligibility requirements in RA3.6 for the specific system are met.

In addition, HERS-verified DWHR is a prescriptive compliance option and a performance compliance credit.

11.6.10.5 Multifamily With Central Water Heating Systems

The HERS verification for central water heating recirculation systems includes verification of multiple distribution lines for central recirculation systems and the verification of DWHR systems.

11.6.11 Code in Practice

11.6.11.1 Garden Style Multifamily Case Study

The Garden Style Multifamily Case Study considers a new two-story garden style multifamily building in Burbank, California (Climate Zone (CZ) 9). This is a sample project created for training purposes, and it consists of 7,216 ft² of conditioned floor area with eight dwelling units and no common use areas. The case study tables in this chapter compare the proposed building water heating system features to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Figure 74: Garden Style Multifamily Case Study: Heat Pump Water Heater in Closet with Ducts to Outside

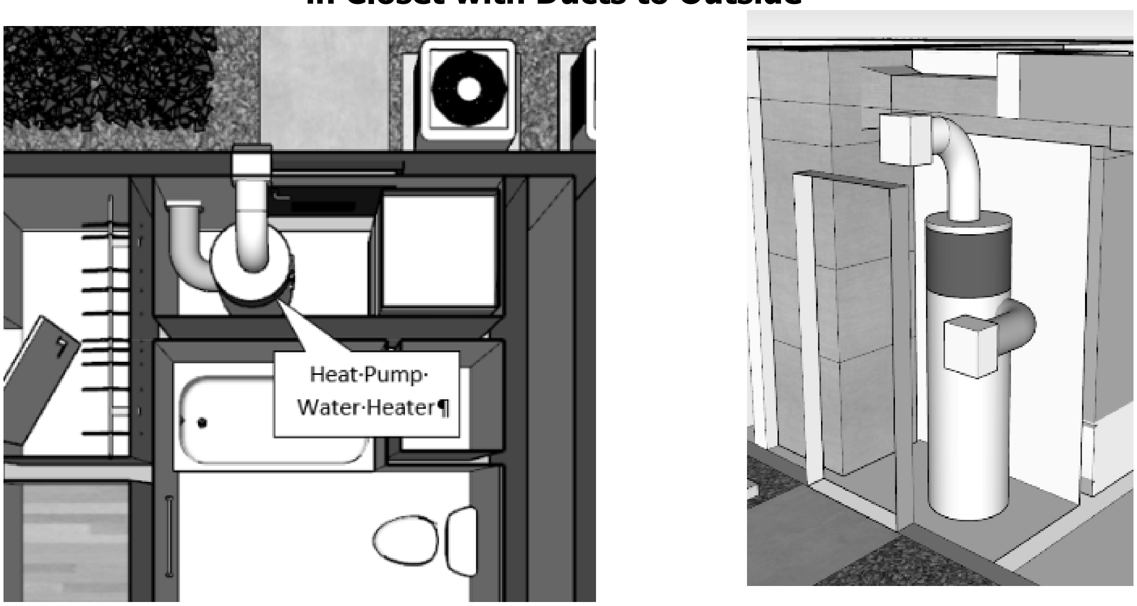


Table 11-56: Garden Style Multifamily Water Heating Schedule

Heat Pump Water Heater: One (1) 50 gallon heat pump water heater per dwelling unit	**Type:** 50 gallon 240 volt heat pump water **Efficiency**: NEEA Advanced Water Heater Specification Tier 3 (NEEA Tier 3), UEF ≥ 2.73	**Ducts:** Air inlet and exhaust outlet ducts installed to the outside	Water Heater Locations: 1st Floor: Exterior closets 2nd Floor: Interior closets	**Distribution:** Standard distribution, ¾ inch hot water piping insulated to R-7.7

Source: California Energy Commission

The proposed heat pump water heating system meets Mandatory efficiency and pipe insulation requirements, and it complies prescriptively by meeting the Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heater Specification

Tier 3 with standard distribution. NEEA maintains a list of qualified heat pump water heaters that are rated from Tier 1 lowest efficiency to Tier 5 highest efficiency: https://neea.org/img/documents/HPWH-qualified-products-list.pdf. The Prescriptive compliance option selected for this case study requires a product from the list rated at NEEA Tier 3 or higher, but the proposed water heating system would also comply as a non-NEEA-rated 240 volt heat pump water heater. Heat pump water heating systems in CZ 9 do not require Prescriptive compact distribution or drain water heat recovery

Table 11-57: Garden Style Multifamily Case Study Compared to Mandatory and Prescriptive Service Water Heating Requirements (Climate Zone 9)

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Multifamily Building	New two-story garden style multifamily building, eight dwelling units, no common use areas, Burbank, CA	Sections 160.4, 110.3 Title 20 Section 1605.1 Table F-2	Section 170.2(d), New multifamily building ≤ three stories, Climate Zone (CZ) 9	Case study Mandatory and Prescriptive compliance rated for each feature below as “Yes” (complies), “No” (does not comply) or “N/A” (not applicable). If “No”, see compliance options provided.
Total Conditioned Floor Area (CFA)	7,216 ft²	7,216 ft²	7,216 ft²	
Fuel Type	Electricity	No Mandatory fuel type requirements	Electricity or Dual Fuel	Mandatory: NR Prescriptive: Yes

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Equipment Type	One (1) 50 gallon storage heat pump water heater per dwelling unit, located in closet (1st floor exterior closet, 2nd floor interior closet), ducted to the outside	Meet or exceed Mandatory requirements for proposed system type	CZ 9: One (1) 240 volt heat pump water, or One (1) NEEA Tier 3 heat pump water heater, or A tankless gas water heater with input ≤ 200 kBtuh	Mandatory: Yes Prescriptive: Yes
Efficiency	NEEA Advanced Water Heater Specification Tier 3 (NEEA Tier 3), UEF ≥ 2.73	Meet or exceed current Federal minimum for storage electric water heater ≥ 20 gallons and ≤ 55 gallons (assumes high draw): UEF ≥ 0.93	CZ 9: NEEA Tier 3 or higher Note: Typical heat pump water heaters have UEF between 2.0 and 4.0, well over the storage electric resistance Federal minimums.	Mandatory: Yes Prescriptive: Yes
Distribution	Standard distribution, ¾ inch hot water piping insulated to R-7.7	Pipe insulation per Table 160.4 for water temperatures from 105°F to 140°F	Standard distribution	Mandatory: Yes Prescriptive: Yes
Controls	None		None	Mandatory: Yes Prescriptive: Yes
Verifications	None		None	Mandatory: Yes Prescriptive: Yes

Source: California Energy Commission

11.6.11.2 Mid-Rise Multifamily Case Study

The Mid-Rise Multifamily Case Study covers a new five-story multifamily building in Sacramento, California (Climate Zone (CZ) 12). This is a sample project created for training purposes, and it includes 112,044 ft² of conditioned floor area with 88 dwelling units, shared residential corridors, laundry rooms, fitness center and lounge, plus ground floor retail. The case study tables in this chapter compare the proposed building water heating system features to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Figure 75: Mid-Rise Multifamily Case Study: Central Heat Pump Water Heater on Roof

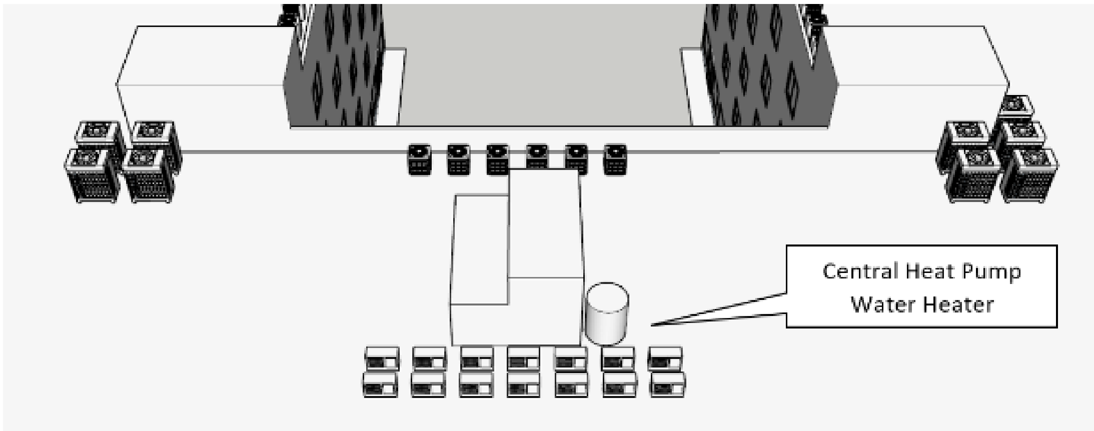


Table 11-58: Mid-Rise Multifamily Water Heating Schedule: Dwelling Units

Central Heat Pump Water Heating System: Central heat pump water heating system serving all 88 dwelling units: (13) NEEA-rated, 43 gallon, small integrated packaged electric heat pump water heaters, electric resistance loop tank with one heater, 300 gallon volume, R-16 tank insulation	Type: Central Heat Pump Water Heater Efficiency: UEF = 3.09	Water Heater Location: Roof of building	Distribution: Recirculation distribution, 1 inch hot water piping insulated to R-12.5, recirculation pump controls based on hot water demand and return temperature

Table 11-59: Mid-Rise Multifamily Water Heating Schedule: Retail and Multifamily Common Use

Electric Water Heater: One (1) 40 gallon storage electric resistance water heater	Type: 40 gallon storage electric resistance Efficiency: UEF = 0.93	Water Heater Location: Interior closet	Distribution: Standard distribution, first 8 feet of hot and cold water pipes insulated, ¾ inch hot water piping insulated to R-7.7

Table 11-60: Mid-Rise Multifamily Case Study Compared to Mandatory and Prescriptive Service Water Heating Requirements (Climate Zone 12) General Information, Total Conditioned Floor Area, Fuel and Equipment Types

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Mid-Rise Multifamily Building	New five-story mid-rise multifamily building, 88 dwelling units, common use areas, ground floor retail, Sacramento, CA	Sections 160.4, 110.3 Title 20 Section 1605.1 Table F-2	Section 170.2(d), Reference Appendix JA14 New multifamily building ≥ four stories, Climate Zone (CZ) 12	Case study Mandatory and Prescriptive compliance rated for each feature below as "Yes" (complies), "No" (does not comply) or "N/A" (not applicable). If "No", see compliance options provided.
Conditioned Floor Area (CFA)	Dwelling Units: 78,384 ft²	78,384 ft²		
	Common Use Multifamily: 17,487 ft²	17,487 ft²		
	Nonresidential: 16,173 ft²	16,173 ft²		
	Total: 112,044 ft²	112,044 ft²		
Fuel and Equipment Types	MF DU: Central heat pump water heating system serving all 88 dwelling units: (13) NEEA-rated, 43 gallon, small integrated packaged electric heat pump water heaters, located on the roof, electric resistance loop tank with one heater, 300 gallon volume, R-16 tank insulation	Meet or exceed Mandatory requirements for proposed system type	CZ 12: Central electric heat pump water heating system meeting 170.2(d)2	Mandatory: Yes Prescriptive: Yes
	MF CU and Retail: One (1) 40 gallon storage electric resistance water heater	Meet or exceed Mandatory requirements for proposed system type	N/A	Mandatory: Yes Prescriptive: N/A

Source: California Energy Commission

Table 11-61: Efficiency, Distribution, Controls and Verifications

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Efficiency	MF DU: UEF = 3.09	Meet or exceed current Federal minimum for storage electric water heater ≥ 20 gallons and ≤ 55 gallons (assumes high draw): UEF ≥ 0.93	CZ 12: Central electric heat pump water heating system meeting 170.2(d)2	Mandatory: Yes Prescriptive: Yes
	MF CU and Retail: UEF ≥ 0.93	Same as MF DU	N/A	Mandatory: Yes Prescriptive: N/A
Distribution	MF DU: Recirculation distribution, 1 inch hot water piping insulated to R-12.5	Table 160.4-A: 1 inch multifamily hot water pipe, requires 1.5 inch R-12.5 pipe insulation	Recirculation distribution with pump controls based on hot water demand and return temperature	Mandatory: Yes Prescriptive: Yes
	MF CU and Retail: Standard distribution meeting Mandatory pipe insulation	120.3: First 8 feet of hot and cold water pipes insulated, ¾ inch hot water pipe, requires 1 inch R-7.7 pipe insulation	N/A	Mandatory: Yes Prescriptive: N/A
Controls	MF DU: Recirculation pump controls based on hot water demand and return temperature	N/A	Recirculation pump controls based on hot water demand and return temperature	Mandatory: N/A Prescriptive: Yes
	MF CU and Retail: None	N/A	N/A	Mandatory: N/A Prescriptive: N/A
Verifications	Design documentation per Reference Appendix JA14.4	N/A	Design documentation per Reference Appendix JA14.4	Mandatory: N/A Prescriptive: Yes

Source: California Energy Commission

The proposed water heating system meets all Mandatory and Prescriptive requirements, so it complies with the Energy Code as designed. The dwelling units clearly are the primary hot water users in this project, and the Energy Code has both Mandatory and Prescriptive requirements to make multifamily water heating systems more energy efficient. In Climate Zone 12, the Prescriptive central heat pump water heating system option helps California move toward the state goal of reducing carbon emissions.

11.7 Indoor and Outdoor Lighting

This chapter covers requirements for lighting in multifamily buildings, including dwelling units, interior common use areas, and outdoor areas. Requirements for lighting in nonresidential spaces in mixed use buildings are covered in Chapter 5 (Nonresidential Manual).

Lighting requirements in multifamily buildings vary between dwelling units, common use areas and outdoor areas. For dwelling units, all the lighting requirements are mandatory. There are luminaire requirements and lighting control requirements for dwelling unit lighting installations. For lighting in common use areas and outdoor areas, requirements include mandatory, prescriptive and performance options, and calculations of lighting power and maximum lighting power thresholds.

Table 11-62 provides an overview of the location of the lighting requirements in the *2022 Energy Code* by system building type and where descriptions reside in this document.

Table 11-62: Overview of Multifamily Lighting Requirements

Lighting Application	Mandatory Requirements	Prescriptive Requirements	Performance Requirements	Manual Section
Dwelling Unit	§110.9, §160.5(a)	N/A	N/A	11.8.2
Common Use Area Indoor	§110.9, §160.5(b), §160.5façade	§170.2(e)1, §170.2(e)2, §170.2(e)3, §170.2(e)4	§170.1	11.8.4, Chapter 5
Outdoor	§110.9, §160.5(c), §160.5(e)	§170.2(e)6	§170.1	11.8.5, Chapter 6
Signs	§160.5(d)	§170.2(e)7	§170.1	Chapter 7

11.7.1 What's New for the 2022 California Energy Code

This section summarizes changes to the requirements for multifamily lighting for the 2022 Energy Code.

- Compiles all lighting requirements for all parts of multifamily buildings into a standalone Multifamily Standard. Requirements for dwelling unit lighting largely align with the single-family residential lighting standards, and requirements for common use areas and outdoor areas in multifamily buildings largely align with the nonresidential lighting standards.

- Eliminates building proportion thresholds for common use areas and consolidates all requirements for multifamily common use areas under a single system.
- Eliminates all thresholds for variable outdoor lighting requirements and consolidates multifamily outdoor lighting requirements under a single system.

11.7.2 Dwelling Unit Mandatory Lighting Requirements

160.5(a), JA8

All requirements relating to lighting within dwelling units and any outdoor lighting controlled from within dwelling units are mandatory. All requirements for dwelling unit lighting align with the applicable single-family residential lighting requirements. Requirements for dwelling unit lighting are described in the sections below.

11.7.2.1 Dwelling Unit Luminaire Requirements

The Standards for dwelling unit lighting require all permanently installed luminaires to be high luminous efficacy, as specified in §160.5(a). Permanently installed lighting is defined in §100.1 and includes:

- Lighting attached to walls, ceilings, or columns.
- Track and flexible lighting systems.
- Lighting inside permanently installed cabinets.
- Lighting attached to the top or bottom of permanently installed cabinets.
- Lighting attached to ceiling fans.
- Lighting integral to exhaust fans.
- Lighting integral to garage door openers if it is used as general lighting, is switched independently from the garage door opener, and does not automatically turn off after a pre-determined amount of time.

The following are examples of non-permanently installed lighting:

- Portable lighting as defined by §100.1 (including, but not limited to, table and freestanding floor lamps with plug-in connections)
- Lighting installed by the manufacturer in refrigerators, stoves, microwave ovens, exhaust hoods for cooking equipment

Table 11-63 summarizes the requirements for dwelling unit high luminous efficacy luminaires. There are luminaires automatically classified as high luminous efficacy, luminaires that must use JA8-certified light sources or lamps, and recessed downlight luminaires in ceilings. These categories are described in more detail in the following sections.

Table 11-63: Summary of Compliant Luminaire Types for Dwelling Units

High Luminous Efficacy Luminaires*	JA8 High Luminous Efficacy Lighting – Lamps and Light Sources that must be JA8-certified	Recessed Downlight Luminaires in Ceilings
• LED light sources installed outdoors • Inseparable solid-state lighting (SSL) luminaires containing colored light sources for decorative lighting purpose • Pin-based linear fluorescent luminaires or compact fluorescent luminaires using electronic ballasts • High intensity discharge (HID) light sources including pulse-start metal halide luminaires and high pressure sodium luminaires • Luminaires with induction lamp and hardwired high frequency generator • Ceiling fan light kits subject to federal appliance regulations	• Light sources installed in ceiling recessed downlight luminaires. • LED luminaires with integral sources • Screw-based LED lamps (A-lamps, PAR lamps, etc.) • Pin-based LED lamps (MR-16, AR-111, etc.) • Any light source or luminaire not listed elsewhere in this table	• Must not have screw-based sockets • Must contain JA8-certified light sources

11.7.2.2 Dwelling Unit Luminaires – High Luminous Efficacy by Default

Luminaires in any of the following categories are classified high luminous efficacy and do not have to comply with the requirements of Reference Joint Appendix JA8 (refer to next section for details).

a. LED luminaires installed outdoors
b. Inseparable solid-state lighting (SSL) luminaires containing colored light sources for decorative lighting purpose.
c. Pin-based linear fluorescent luminaires or compact fluorescent luminaires using electronic ballasts
d. High intensity discharge (HID) luminaires including pulse-start metal halide luminaires and high pressure sodium luminaires
e. Luminaires with induction lamp and hardwired high frequency generator
f. Ceiling fan light kits that are subject to federal appliance regulations.

11.7.2.3 Dwelling Unit Luminaires – JA-8 Compliant

Luminaires not listed in the previous section must have an integral light source or removable lamp that meets the performance requirements of JA8. The requirements in JA8 allow any type of light source, such as LED, as long as it provides energy-efficient lighting and meets minimum performance characteristics.

In addition to setting minimum efficacy requirements (lumens/Watt), JA8 establishes performance requirements that ensure accurate color rendition, dimmability, and reduced noise and flicker during operation.

Luminaires with integral sources, such as LED luminaires, must be certified to the Energy Commission as meeting the JA8 requirements. Luminaires that have changeable lamps (such as screw-base luminaires) must be installed with JA8-certified lamps.

Luminaires and lamps that are certified to the Energy Commission must be marked on the product as described in JA8. Lamps that will be installed in elevated temperature applications such as in enclosed luminaires must have a JA8-2022-E marking to indicate that the product has passed the more stringent ENERGY STAR Elevated Temperature Life test.

Luminaires that can be classified as high luminous efficacy by meeting the requirements of JA8 include:

- LED luminaires with integral light sources that are certified to the Energy Commission.
- Ceiling recessed downlight luminaires with JA8 certified light sources (the luminaire must not contain screw-based lamp sockets).
- Screw-based luminaires with JA8-certified lamps.
- Low-voltage pin-based luminaires with JA8-certified lamps.

Almost any luminaire can be classified as high luminous efficacy, as long as the luminaire is installed with a JA8 certified lamp or light source. The exception is recessed downlight luminaires in ceilings, which must meet additional requirements.

The Energy Commission maintains a database of certified JA8 certified luminaires, lamps, and light sources. The database can be accessed using a Quick Search Tool or an Advanced Search.

11.7.2.4 Recessed Downlight Luminaires in Dwelling Unit Ceilings

In addition to the high luminous-efficacy requirements described above, there are several additional requirements for dwelling unit downlight luminaires that are recessed in ceilings.

Recessed downlight luminaires are limited to specific light sources and lamp types that may be used. Recessed downlight luminaires:

1. Must contain light sources that are JA8-certified.
2. Must not contain screw-based lamps.
3. Must not contain light sources that are labeled not for use in enclosed luminaires or not for use in recessed luminaires.

All recessed downlight luminaires must contain a light source or lamp that is JA8-certified, such as an integral LED source or LED lamp. Screw-based lamps such as LED A-lamps or LED PAR lamps are not allowed. Pin-based lamps such as LED MR-16 lamps are allowed in recessed luminaires as long as they are JA8-certified.

In addition to the light source and lamp requirements listed, recessed downlight luminaires in ceilings must meet all the following requirements:

1. Have a label that certifies the luminaire is airtight with air leakage less than 2.0 cubic ft. per minute at 75 Pascals when tested in accordance with ASTM E283 (exhaust fan housings with integral lighting are not required to be certified airtight).
2. Be sealed with a gasket or caulk between the luminaire housing and ceiling, and have all air leak paths between conditioned and unconditioned spaces sealed with a gasket or caulk, or be installed per manufacturer's instructions to maintain airtightness between the luminaire housing and ceiling.
3. Meet the clearance and installation requirements of California Electrical Code Section 410.116 for recessed luminaires which requires the following.
    - A recessed luminaire that is not identified for contact with insulation, non-Type IC, must have all recessed parts spaced not less th½1/2 inch from combustible materials. The points of support and the trim finishing off the openings in the ceiling must be permitted to be in contact with combustible materials.
    - A recessed luminaire that is identified for contact with insulation, Type IC, must be permitted to be in contact with combustible materials at recessed parts, points of support, and portions passing through or finishing off the opening in the building structure.
    - Thermal insulation must not be installed above a recessed luminaire or within 3 inches of the recessed lumina're's enclosure, wiring compartment, ballast, transformer, LED driver, or power supply unless the luminaire is identified as Type IC for insulation contact.

Luminaires that meet the air leakage requirement or luminaires that are Type IC rated will have this information listed on luminaire cut sheets or packaging. Contractors are responsible for ensuring that luminaires are properly sealed to prevent air leakage between the luminaire housing and ceiling.

Recessed luminaires that are marked for use in fire-rated installations and recessed luminaires installed in non-insulated ceilings are exempt from the air leakage requirement and sealing requirement, however, must meet all other requirements for recessed luminaires.

11.7.2.5 Enclosed Luminaires and Recessed Luminaires other than Ceiling-Recessed Downlight Luminaires

For enclosed luminaires and recessed luminaires other than ceiling-recessed downlights, the installed light source must be JA8 compliant and meet the elevated temperature requirement. The JA8-compliant lamps and light sources must be marked with "JA8-2022-E" to signify that they are suitable to be installed in an enclosed or recessed luminaire.

11.7.2.6 Screw-Base Luminaires

For screw-base luminaires to be installed in residential spaces, the installed lamps must be JA8 certified. Recessed downlight luminaires in ceilings cannot have screw base lamp sockets.

11.7.2.7 Navigation Lighting – Night Lights, Step Lights, and Path Lights in Dwelling Units

Navigation lighting such as night lights, step lights, and path lights must either:

1. Be rated to consume no more than 4 watts; or
2. Comply with luminaire efficacy requirement in §160.5(a)1A and Table 160.5-A.

11.7.2.8 Lighting internal to Drawers, Cabinets, and Linen Closets

Luminaires or light sources internal to drawers, cabinets, and linen closets must either:

1. Have an efficacy of 45 lumens per watt or greater
2. Comply with luminaire efficacy requirements in §160.5(a)1A and Table 160.5-A.

Light sources in drawers and cabinets with opaque fronts or doors must also have controls that automatically turn the light off when the drawer or door is closed.

Example 11-37: Screw-based luminaires

Question

I am using a screw-based luminaire that is rated to take a 60W lamp for lighting over a sink, and I plan to install a 10W LED lamp. Does it meet the dwelling unit lighting requirement for screw-based luminaires?

Answer

If the LED lamp is JA8-certified and marked JA8-2022 or JA8-2022-E, then it meets the dwelling unit lighting requirement for screw-based luminaires in §160.5(a)1B and Table 160.5-A.

Example 11-38: Kitchen Exhaust Hood Lighting

Question

I am installing an exhaust hood over my kitchen range that has lamps in it. Do these lamps have to be high efficacy?

Answer

This lighting is integrated into the appliance and does not have to meet the dwelling unit luminaire efficacy requirements for permanently installed lighting.

11.7.2.9 Blank Electrical Boxes

The number of blank electrical boxes that are more than five feet above the finished floor and do not contain a luminaire or other device must be no greater than the total number of bedrooms in the dwelling unit. These electrical boxes must be served by a dimmer, vacancy sensor control, low voltage wiring, or fan speed control.

11.7.3 Dwelling Unit Lighting Control Requirements

As with the luminaire requirements described in the previous section, all dwelling unit lighting control requirements are mandatory.

11.7.3.1 Lighting Control Installation Requirements

Following are general requirements for how and where lighting controls must be implemented in multifamily dwelling units:

A. Readily Accessible Manual Controls

All permanently installed luminaires must have readily accessible wall-mounted controls that permit the luminaires to be manually turned on and off. Per §100.1 Definitions, readily accessible is capable of being reached quickly for operation, repair, or inspection without requiring climbing or removing obstacles, or resorting to access equipment

B. Multiple Switches

A lighting circuit can be controlled by more than one switch, such as by three-way or four-way switches. For a lighting circuit with multiple switches, and where a dimmer or vacancy sensor has been installed to comply with §160.5(a), the following requirements must be met:

1. No controls must bypass the dimmer or vacancy sensor function.
2. The dimmer or vacancy sensor must comply with the applicable requirements of §110.9(b).

C. Energy Management Control Systems (EMCS) and Multiscene Programmable Controllers

An EMCS or a multiscene programmable controller can be installed to meet the dimming, occupancy, and lighting control requirements in §160.5(a)2 if it provides the functionality of the specified controls in accordance with §110.9 and the physical controls specified in §160.5(a)2A.

D. Exhaust Fan Integrated Lighting

Integrated lighting in exhaust fans must be controlled independently from the fan.

E. Light Sources in Drawers and Cabinets

Undercabinet lighting, undershelf lighting, and interior lighting of display cabinets must be controlled separately from ceiling-installed lighting such that one can be turned on without turning on the other.

Drawers and cabinetry with internal lights and opaque fronts or doors must have controls that turn the lights off when the drawer or door is closed.

F. Independent Control of Other Lighting

Switched outlets must be controlled separately from ceiling-installed lighting such that one can be turned on without turning on the other.

G. Ceiling Fan Lighting

Ceiling fans with integrated light sources can be controlled with a remote control for on, off and dimming control. The remote control does not need to be wall mounted.

H. Spaces Required to Have Vacancy Sensors or Occupancy Sensors

The following dwelling unit spaces are required to have at least one installed luminaire in the space controlled by an occupancy or vacancy sensor:

- Bathrooms
- Garages
- Laundry Rooms
- Utility Rooms
- Walk-in Closets

I. Luminaires Required to Have Dimming Controls

Lighting in habitable spaces such as living rooms, dining rooms, kitchens, and bedrooms must have readily accessible wall-mounted dimming controls that allow the lighting to be manually adjusted up and down.

The exceptions are as follows:

- Ceiling fans may provide control of integrated lighting via a remote control.

- Luminaires connected to a circuit with controlled lighting power less than 20 watts or controlled by an occupancy or vacancy sensor providing automatic-off functionality.
- Navigation lighting such as night lights, step lights, and path lights less than 5 watts, and lighting internal to drawers and cabinetry with opaque fronts or doors with automatic off controls.

Also, lighting integral to appliances including kitchen range hoods and exhaust fans are not required to be provided with dimming controls.

Forward phase cut dimmers controlling LED light sources in these spaces must comply with NEMA SSL 7A. The combined use of a NEMA SSL-7A-compliant dimmer with LED luminaires can ensure flicker free operation when the luminaire is dimmed. This dimmer/light source compatibility information is included in dimmer cut sheets or dimmer product packaging.

Example 11-39: Using vacancy sensors and dimmers

Question

Can I install vacancy sensors and dimmers in hallways and non-walk-in closets even though the Energy Code does not require it?

Answer

Installing controls such as vacancy sensors and dimmers in hallways and closets is allowed.

A vacancy sensor automatically turns lighting off when a space is unoccupied. This can save energy compared to a manual on-off switch where the light may be left on while the space is unoccupied.

Using vacancy sensors is recommended for any application where they can provide additional energy savings for the homeowner or occupant.

A dimmer varies the intensity of the light to suit the occasion or the time of the day. When less light is needed, the homeowner can reduce the light intensity with a dimmer to save energy.

11.7.3.2 Lighting Control Functionality Requirements

All installed lighting control devices and systems must meet the functionality requirements in §110.9(b). In addition, all components of a lighting control system installed together must meet all applicable requirements for the application for which they are installed as required in §160.5 and §170.2(e).

Designers and installers should review features of their specified lighting control products for meeting the requirements of §110.9(b) as part of the compliance process.

A. Time-Switch Lighting Controls

Time-switch lighting control products must provide the functionality listed in §110.9(b)1 of the Energy Code.

B. Dimmers

Dimmer products must provide the functionality listed in §110.9(b)3 of the Energy Code.

Forward phase cut dimmers used with LED lighting must comply with NEMA SSL 7A, as mentioned earlier in this manual.

C. Occupant Sensing Controls

Occupant sensing control products (including occupant sensors, partial-ON occupant sensors, partial-OFF occupant sensors, motion sensors, and vacancy sensor controls) must provide the functionality listed in §110.9(b)4 of the Energy Code.

One important feature of occupant sensing controls is that it must automatically reduce lighting or turn the lighting off within 20 minutes after the area has been vacated.

Occupant sensing control systems may consist of a combination of single or multi-level occupant, motion, or vacancy sensor controls, if components installed for manual-on compliance don't allow occupants to change the functionality from manual-on to automatic-on.

D. Using Vacancy Sensors or Occupancy Sensors

Occupancy sensors automatically turn lights on when a space becomes occupied, and automatically turn lights off within 20 minutes of the room being vacated.

Vacancy sensors, also known as manual-on/automatic-off occupant sensors, require occupants to turn lights on manually, and automatically turn lights off within 20 minutes of the room being vacated.

Occupancy and vacancy sensors are required to provide the occupant with the ability to manually turn the lights on and off. The manual off feature provides the occupants with the flexibility to control the lighting environment by turning off the lights when they are not needed.

The Energy Code allows occupancy sensors or vacancy sensors to be installed to meet the automatic off control requirements.

Example 11-40: Bathroom vacancy sens–s--manual off

Question

For a bathroom with vacancy sensor, the lighting turns off automatically once the space is unoccupied. Is it necessary to provide a manual off control?

Answer

Vacancy and occupancy sensors must provide the occupant with the option to turn the lights off manually.

If an occupant forgets to turn the lights off when a room is unoccupied, the vacancy or occupancy sensor must turn the lights off automatically within 20 minutes. The occupant must also have the ability to turn the lights off upon leaving the room.

This provides occupants flexibility to control the lighting environment and can achieve greater energy savings, since the lights can be turned off when they are not needed.

Example 11-41: Use of automatic-shut off controls

Question
What type of automatic shut off control can be used in a bathroom, garage, laundry room, utility room, or walk-in closet?

Answer
Occupant or vacancy sensing controls that provide automatic off functionality must be installed to meet the dwelling unit lighting control requirements for bathrooms, garages, laundry rooms, utility rooms, and walk-in closets.

11.7.3.3 Outdoor Lighting Controlled from Dwelling Units

All outdoor lighting attached to the building and controlled from within the dwelling unit must be high luminous efficacy. Outdoor LED luminaires and LED light sources installed outdoors are automatically classified as high luminous efficacy and are not required to comply with JA8.

Outdoor lighting controlled from within the dwelling unit must be controlled by a manual ON and OFF control switch and one of the following automatic control types:

- Photocontrol and either a motion sensor or an automatic time switch control
- Astronomical time clock control

Any override to the above automatic controls to ON must return to automatic control operations within six hours.

11.7.4 Common Service Area Lighting

This section covers the requirements for multifamily indoor common service area lighting design and installation. The requirements for common service area lighting largely align with indoor lighting requirements for nonresidential buildings.

The Energy Code requires that total common service area lighting power is within a specified budget, and lighting controls are installed for the efficient operation of installed lighting. This ensures that energy efficient equipment is used to satisfy common use area lighting needs.

In addition to meeting all mandatory requirements, design teams can choose between prescriptive and performance approaches for compliance. These requirements and approaches are described in sections below.

Lighting systems in common use areas providing shared provisions for living, eating, cooking, or sanitation to dwelling units that would otherwise lack these provisions may instead comply with the requirements for dwelling units per §160.5(a) and detailed in Section 11.7.1.

11.7.4.1 Mandatory Requirements

§110.9, §160.5(b)

The following mandatory requirements must be met regardless of the compliance approach used.

Indoor common service area lighting mandatory requirements include:

- Requirements for luminaire classification (according to technology) and installed lighting power determination
- Required indoor lighting controls
- Lighting control acceptance testing
- Lighting control Certificates of Installation

The mandatory indoor lighting requirements for common service areas are analogous to corresponding nonresidential building mandatory indoor lighting requirements.

Refer to Section 5.3 for information on luminaire classification and power requirements.

Refer to Section 5.4 for information on mandatory lighting control requirements.

Refer to Section 5.9.2 and Section 5.11.7 for information on indoor lighting controls acceptance testing requirements.

Although not related exclusively to lighting, the Energy Code imposes mandatory requirements for electrical power distribution systems. See Section 11.9 for information about mandatory requirements for electrical power distribution systems.

11.7.4.2 Prescriptive Requirements

The prescriptive compliance approach establishes an adjusted lighting power for a proposed design as well as a maximum lighting power that can be installed based on the prescriptive method and the common use area space types. The process for calculating adjusted lighting power for multifamily indoor common use area lighting is closely aligned to the corresponding process for nonresidential buildings. Please refer to Section 5.6 for information on the prescriptive compliance approach for indoor lighting.

The differences between the prescriptive requirements for common use areas in multifamily buildings and nonresidential buildings include:

Common use areas may not use the complete building method for lighting power allowance calculations. Only the area category method or tailored method may be used per §170.2(e)3.

The primary function area types included in the lighting power density Tables 170.2-M, Table 170.2-N, and Table 170.2-O differ from the corresponding nonresidential primary function area types included in Table 140.6-C, Table 140.6-D, and Table 140.6-E respectively.

The primary function area types included in Table 170.2-M, Table 170.2-N, and Table 170.2-O are specific to multifamily common use areas and do not include nonresidential primary function area types.

Common use areas providing shared provisions for living, eating, cooking, or sanitation to dwelling units that would otherwise lack these provisions may instead comply with the requirements for dwelling units per §160.5(a) and detailed in Section 11.7.1.

11.7.4.3 Performance Requirements

The performance approach is applicable when the designer uses a compliance software program approved by the Energy Commission to demonstrate that the proposed build'ng's energy consumption (including common use area indoor lighting power) meets the energy budget. The performance approach uses the prescriptive approach lighting power allotment in calculating the building's custom energy budget.

No additional lighting power allotment is gained by using the performance method unless it is traded from the space conditioning, mechanical ventilation, service water heating, envelope, or covered process systems.

The energy budget does not include the dwelling unit lighting mandatory requirements and cannot be traded off using the performance approach.

The performance approach for common service area lighting is analogous to the corresponding code section for nonresidential buildings as applied to multifamily common use areas. Please refer to Section 5.8.

11.7.5 Outdoor Lighting

This section covers the requirements for multifamily outdoor lighting systems and related lighting design and installation, luminaires, and lighting controls. In a mixed use building with a multifamily occupancy, the multifamily outdoor lighting requirements described in this section are to be used for the entire site.

For outdoor lighting controlled from within multifamily dwelling units please see Section 11.8.3.3.

11.7.5.1 Mandatory Requirements

§110.9 and §160.5(c)

The mandatory outdoor lighting requirements for multifamily buildings largely align with mandatory outdoor lighting requirements for nonresidential buildings.

A. Luminaire Shielding Requirements

§160.5(c)1

Refer to Section 6.4.1 for information on luminaire shielding requirements.

11.7.5.2 Outdoor Lighting Controls Requirements

§160.5(c)2

Refer to Section 6.4.2 for information on outdoor lighting controls requirements.

11.7.5.3 Outdoor Lighting Controls Acceptance Testing Requirements

§160.5(e)

Refer to Section 6.7.5 and Section 6.7.6 for information on outdoor lighting controls acceptance testing requirements.

11.7.5.4 Prescriptive Requirements

§170.2(e)

An outdoor lighting installation complies with the Energy Code if the actual outdoor lighting power is no greater than the allowed outdoor lighting power.

The process for determining actual lighting power for multifamily outdoor lighting applications is consistent with the requirements for nonresidential lighting, as described in Section 6.5.1.

Allowed outdoor lighting power densities for multifamily buildings are structured using a layered approach. The first layer of allowed lighting power is general hardscape for the entire site. After the allowed lighting power has been determined for this first layer, additional layers of lighting power are allowed for specific applications when they occur on the site. The total allowed lighting power is the combined total of the allowed lighting power layers.

The allowed outdoor lighting power must be determined according to the outdoor lighting zone in which the site is located as defined in §10-114. Outdoor Lighting Zone definitions for multifamily lighting are analogous to the corresponding code section for nonresidential buildings. Please refer to Section 6.3 for information on outdoor lighting zones.

Figure 11-76. Concept of a Layered Lighting Approach for Outdoor Lighti–g - Lighting Power Allowance (LPA)

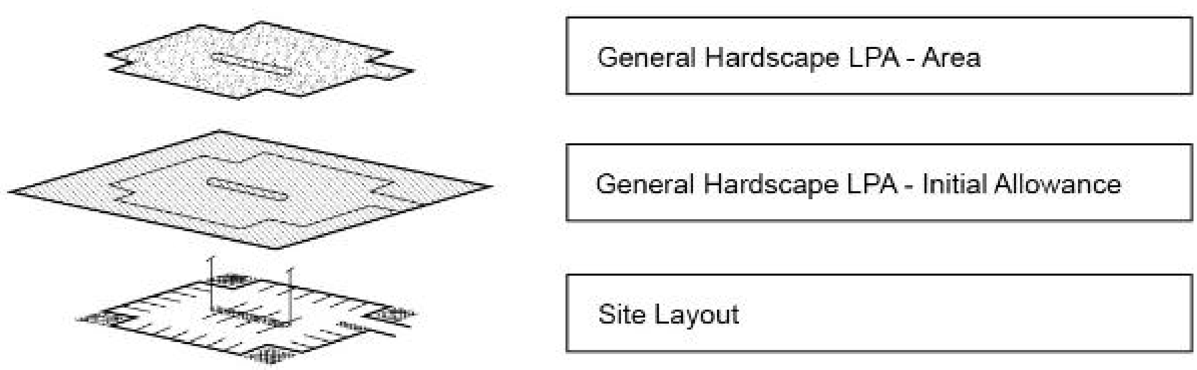


Image Source: Energy Solutions

The outdoor lighting applications addressed by the Energy Code are shown in the first two columns of Table 11-64. The first column is general site illumination applications, which allow trade-offs within the outdoor portion only. The second column is specific outdoor lighting applications, which do not allow trade-offs, and are considered "*use it or lose it*". The lighting applications in the third column are exempt from lighting power requirements. However, these lighting applications must meet applicable lighting control requirements.

For the purpose of determining outdoor lighting allowances, only those areas where lighting is provided are considered *illuminated areas*, excluding any areas that do not have luminaires, areas that are obstructed by any other structure or within a building, and any areas beyond the property line of the project site. The details of the process for determining the illuminated area for multifamily outdoor lighting are consistent with the requirements for nonresidential outdoor lighting, as described in Section 6.5.

Hardscape is defined in §100.1 as an improvement to a site that is paved and has other structural features, including but not limited to, curbs, plazas, entries, parking lots, site roadways, driveways, walkways, sidewalks, bikeways, water features and pools, storage or service yards, loading docks, amphitheaters, outdoor sales lots, and private monuments and statuary. This definition is also consistent with the nonresidential outdoor lighting Standards, as described in more detail in Section 6.5.2.

Table 11-64: Scope of the Multifamily Outdoor Lighting Requirement

General Hardscape (trade-offs permitted)	Specific Applications (trade-offs not permitted)	Lighting Applications Not Regulated
The general hardscape area of a site must include parking lot(s), roadway(s), driveway(s), sidewalk(s), walkway(s), bikeway(s), plaza(s), bridge(s), tunnel(s), and other improved area(s) that are illuminated.	• Building Entrances or Exits • Primary Entrances for Senior Care Facilities • ATM Machine Lighting • Hardscape Ornamental Lighting • Building Facades • Canopies • Tunnels • Student Pick-u/.Drop-off zone • Outdoor Dining • Special Security Lighting for Retail Parking and Pedestrian Hardscape • Security Cameras	• Temporary outdoor lighting • Required and regulated by FAA • Required and regulated by the Coast Guard. • For public streets, roadways, highways, and traffic signage lighting, and occurring in the public right-of-way • For sports and athletic fields, and children's playground • For public monuments • Signs regulated by §160.5(d) and §170.2(e)7 • For stairs and wheelchair elevator lifts • For ramps that are not parking garage ramps • Landscape lighting • For outdoor theatrical and other outdoor live performances • For qualified historic buildings

Source: California Energy Commission

11.7.5.5

Other outdoor lighting applications that are not included in Energy Code Tables 170.2-R and 170.2-S are assumed to be not regulated by the Energy Code. This includes decorative gas lighting and emergency lighting powered by an emergency source as defined by the California Electrical Code. The text in the above list of multifamily outdoor lighting applications that are not regulated has been shortened for brevity. Please see the section, §170.2(e)6A for details about unregulated lighting applications.

11.7.5.6 Trade-offs

§170.2(e)6B

All outdoor lighting trade-off requirements are analogous to the corresponding code sections for nonresidential buildings as applied to multifamily outdoor lighting. Please refer to Sections 6.5.3-A and 6.5.3-B.

11.7.5.7 Outdoor Lighting Applications Not Regulated by §170.2(e)6

When a luminaire is installed only to illuminate one or more of the applications listed in the rightmost column of Table 11-65, the lighting power for that luminaire must be exempt from §170.2(e)6. The Standards clarify that at least 50% of the light from the luminaire must fall within the unregulated lighting application to qualify as being installed for that application.

Even if the lighting is exempted from the wattage allowance requirements, it is still subject to the lighting controls requirements that may apply to the respective lighting systems.

11.7.5.8 General Hardscape Lighting Allowance

Determine the general hardscape lighting power allowances as follows:

General Hardscape lighting allowance = (Hardscape Area x AWA) + IWA

Where,

1. The general hardscape area of a site must include parking lot(s), roadway(s), driveway(s), sidewalk(s), walkway(s), bikeway(s), plaza(s), bridge(s), tunnel(s), and other improved area(s) that are illuminated, as defined in §100.1. The illuminated hardscape area must include portions of planters and landscaped areas that are within the lighting application and are less than or equal to 10 ft. wide in the short dimensions and are enclosed by hardscape or other improvement on at least three sides.
2. Multiply the illuminated hardscape area by the Area Wattage Allowance (AWA) from Table 11-65 (Table 170.2-R) for the appropriate lighting zone.
3. Determine the Initial Wattage Allowance (IWA). The purpose of the IWA is to provide additional watts for small sites, or for odd hardscape geometries. Add the IWA for general hardscape lighting from Table 11-65 (Table 170.2-R) for the appropriate lighting zone. The IWA may only be used one time per site.

Table 11-65 (from Table 170.2-R): General Hardscape Lighting Power Allowance

Type of Power Allowance	Lighting Zone 0[2]	Lighting Zone 1[2]	Lighting Zone 2[2]	Lighting Zone 3[2]	Lighting Zone 4[2]
Area	No	0.026	0.030	0.038	0.055
Initial	No	300 W	350 W	400 W	450 W

Footnotes to Table:

1 Continuous lighting is explicitly prohibited in Lighting Zone 0. A single luminaire of 15 Watts or less may be installed at an entrance to a parking area, trail head, fee payment kiosk, outhouse, or toilet facility, as required to provide safe navigation of the site infrastructure. Luminaires installed must meet the maximum zonal lumen limits as specified in Section 160.5(c)

46 2 Narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm – as mandated by local, state, or federal agencies to minimize the impact on local, active professional astronomy or nocturnal habitat of specific local fauna – must be allowed a 2.0 lighting power allowance multiplier.

Source: Table 170.2-R from the Standards

Example 11-42: Power Allowance for a Parking Lot

Question

In a parking lot in front of a multifamily building, we are not using the full lighting power allowed according to Table 170.2-R. Can we use the remaining allowance to illuminate the building entrance and the walkways near the store to a higher level?

Answer

Yes. Because general hardscape power allowances are tradable, you may use the unused portion of the power allowance for the parking lot to increase the illumination levels for other lighting applications, including building entrance and walkway areas.

Example 11-43: Calculating the Power Allowance for a Parking Lot

Question

The parking lot illustrated below has two luminaires that are mounted at a height of 25 ft. What is the illuminated hardscape area and what is the general hardscape lighting power allowance? The lot is in Lighting Zone 3.

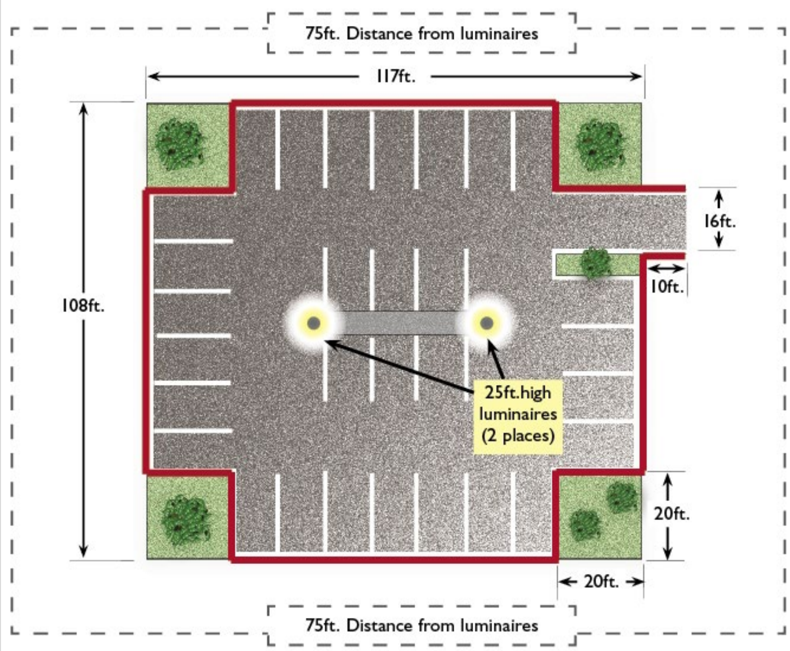


Image: California Energy Commission

Answer

The poles are 40 ft. apart, and using the 10 times mounting height rule, the illuminated area can be as large as 250 ft. by 290 ft. The boundary of this illuminated area extends beyond the edges of the parking lot as well as the entrance driveway, so the entire paved area is considered illuminated. The landscaped island in middle and peninsula below the entrance driveway are less than 10 ft. wide, so they are included as part of the illuminated area. The landscaped cutouts (20 x 20 ft.) in the corners of the parking lot are bound by pavement on only two sides so they are not included. The total paved area is 11,196 sq. ft. [(12,636 sq. ft. + 160 sq. ft. (driveway) – 1,600 sq. ft (cutouts)].

Two allowances make up the general hardscape allowance: Area and Initial. All allowances are based on a Lighting Zone 3 and found in (Table 170.2-R of the Standards).

The area wattage allowance is equal to 425.4 W.

The initial wattage allowance (IWA) is 400 W for the entire site.

The sum of these two allowances gives a total wattage allowance for the site of 825.4 W.

The calculations are tabulated below.

Type of Allowance	Allowance	Area/Perimeter Value	Power Allowance
Initial	400 W	-	400 W
Area	0.038 W/sq. ft.	11,196 sq. ft.	425.4 W
-	-	**Total Power Allowance:**	**825.4 W**

Source: California Energy Commission

The Standards includes a lighting power provision for narrow band spectrum light source application to minimize the impact of electric light on local, active professional astronomy or nocturnal habitat of specific local fauna. The provision is in the format of lighting power multiplier as specified on the footnote of Table 170.2-R (footnote 2). This provision is consistent with the requirement for narrow band spectrum light sources in nonresidential outdoor lighting.

11.7.5.9 Additional Lighting Power Allowances and Requirements

§170.2(e)6Dii

The lighting power allowances for specific applications provide additional lighting power that can be layered in addition to the general hardscape lighting power allowances, as applicable. Some portions of the site may fit use categories that permit the inclusion of an additional lighting allowance for that portion of the site. These specific applications are detailed in Table 11-66 (Table 170.2-S of the Energy Code). Additional allowances for specific applications can be per application, per hardscape area, per specific application unit length, or per specific application area.

As noted previously, all these additional allowances are *use it or lose it* allowances and cannot be traded between applications or to general hardscape lighting. However, general hardscape lighting allowance may be traded to supplement these specific applications.

Table 11-66 (from Table 170.2-S): Additional Lighting Power Allowance for Specific Applications

Lighting Application **WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.**	**Lighting Zone 0**	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
Building Entrances or Exits. Allowance per door. Luminaires must be within 20 ft. of the door.	Not applicable	9 watts	15 watts	19 watts	21 watts
Primary Entrances to Senior Care Facilities Allowance per primary entrance(s) only. Primary entrances are entrances that provide access for the general public. This allowance is in addition to the building entrance or exit allowance above. Luminaires must be within 100 ft. of the primary entrance.	Not applicable	20 watts	40 watts	57 watts	60 watts
ATM Machine Lighting. Allowance per ATM machine. Luminaires must be within 50 ft. of the dispenser.	Not applicable	100 watts for first ATM machine, 35 watts for each additional	100 watts for first ATM machine, 35 watts for each additional	100 watts for first ATM machine, 35 watts for each additional	100 watts for first ATM machine, 35 watts for each additional

Lighting Application **WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.**	**Lighting Zone 0**	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
		ATM machine.	ATM machine.	ATM machine.	ATM machine.
Lighting Application WATTAGE ALLOWANCE PER HARDSCAPE AREA (W/sq. ft.). May be used for any illuminated hardscape area on the site.	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Hardscape Ornamental Lighting. Allowance for the total site illuminated hardscape area. Luminaires must be rated for 100 watts or less and be post-top luminaires, lanterns, pendant luminaires, or chandeliers.	Not applicable	No Allowance	0.007 W/sq. ft.	0.013 W/sq. ft.	0.019 W/sq. ft.
Lighting Application WATTAGE ALLOWANCE PER SPECIFIC AREA (W/sq. ft.). May be used as appropriate provided that only one is used for a given area (i.e., provided that two allowances are not applied to the same area).	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Building Facades. Only areas of building façade that are illuminated must qualify for this allowance. Luminaires qualifying for this allowance must be aimed at the façade and must be capable of illuminating it without obstruction or interference by permanent building features or other objects. This allowance calculation must not include portions of the building facades within 20 ft. of residence bedroom windows.	Not applicable	No Allowance	0.100 W/sq. ft.	0.170 W/sq. ft.	0.225 W/sq. ft.
Canopies and Tunnels. Allowance for the total area within the drip line of the canopy or inside the tunnel. Luminaires must be located under the canopy or tunnel.	Not applicable	0.057 W/sq. ft.	0.137 W/sq. ft.	0.270 W/sq. ft.	0.370 W/sq. ft.
Outdoor Dining. Allowance for the total illuminated hardscape of outdoor dining. Outdoor dining areas are hardscape areas used to serve and consume food and beverages. Qualifying luminaires must be within 2 mounting heights of the hardscape area of outdoor dining.	Not applicable	0.004 W/sq. ft.	0.030 W/sq. ft.	0.050 W/sq. ft.	0.075 W/sq. ft.

Lighting Application **WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.**	**Lighting Zone 0**	**Lighting Zone 1**	**Lighting Zone 2**	**Lighting Zone 3**	**Lighting Zone 4**
Special Security Lighting for Retail Parking and Pedestrian Hardscape. This additional allowance is for illuminated retail parking and pedestrian hardscape identified as having special security needs. This allowance must be in addition to the building entrance or exit allowance.	Not applicable	0.004 W/sq. ft.	0.005 W/ft²	0.010 W/ft²	No Allowance
Security Camera. This additional allowance is for the illuminated general hardscape area. This allowance must apply when a security camera is installed within 2 mounting heights of the general hardscape area and mounted more than 10 ft. away from a building.	Not applicable	No Allowance	0.018 W/ft²	0.018 W/ft²	0.018 W/ft²

Source: California Energy Commission

Most of these allowances are comparable to the same allowance in the nonresidential portions of the code. See section 6.5.3 for more details. The one category of allowance that differs is buildifaçadeade lighting.

façadeng facade lighting is permitted in a similar manner as the nonresidential sections of the code, however, multifamily buildings have a specific stipfaçaden to the facade lighting allowance that the allowance is not permitted to be counfaçader areas of the facade that are within 20 feet of a bedroom window. This means thafaçadeions of the buifaçadefacade will either have no facade lighting or the allowance will be smaller because of the excluded area for the allowance.

See Section 6.5.4-Afaçade detailed discussion of building facade lighting.

Example 11-44: Power Allowance for Multifamily BuifaçadeFacades

Question

Portions of the front facade of a proposed multifamily building in Lighting Zone 3 are going to be illuminated. The front wall dimensions are 80 ft. wide by 50 ft. tall. There is a column of 6 ft. wide bedroomfaçadews, aligned vfaçadelly, in the centerfaçadee facade. All areas of the facafaçadel be illuminated by facade lighting, except those areas of the facade near bedroom windows that are excluded from the facade lighting allowance. What is the allowed front facade lighting power?

Answer

The gross wall area is 4,000 sq. ft. (80 x 50). However, we must subtract all those areas that are within 20 ft. of a bedroom window.

The areas not eligible for power calculations include the 6 ft. width of the column of bedroom windows, plus 20 ft. of width on either side of the windows, or a total of 46 ft. of width:

46 ft. of width on or near bedroom windows x 50 ft. facade height = 2,300 sq. ft.

The net wall area used to determine facade lighting allowance: 4,000 sq. ft. – 2,300 sq. ft. = 1,700 sq. ft.

From Table 11-67 (Table 170.2-S of the Standards), the allowed facade lighting power density in Lighting Zone 3 is 0.17 W/ sq. ft.

The calculated allowed power based on net wall area is 1,700 sq. ft. x 0.17 W/ sq. ft. = 289 W.

The allowed power is therefore the smaller of actual wattage used for facade lighting or 289 W.

11.7.6 Additions and Alterations

Additions to dwelling units must meet all applicable mandatory dwelling unit lighting requirements as described in Section 11.8.2. For alterations to dwelling units, any existing lighting may stay in place, but all newly installed lighting must meet the mandatory dwelling unit lighting requirements.

For details on lighting requirements for additions and alterations to multifamily common use areas, please refer to Section 5.10.

For details on lighting requirements for additions and alterations to multifamily outdoor areas, please refer to Section 6.6.

11.7.7 Code in Practice

11.7.7.1 CASE Example 1: A Garden Style Multifamily Building

This case example considers a new two-story garden style multifamily building in Burbank, California (Climate Zone (CZ) 9) . This is a sample project created for training purposes, and it consists of 7,216 ft² of conditioned floor area with eight dwelling units and no common use areas. The tables below provide details about the proposed lighting design and the possible compliance options for meeting the Energy Code which includes mandatory and prescriptive requirements for indoor and lighting outdoor lighting.

Note that the mandatory requirements in §160.5(a) govern the lighting installed inside the dwelling units and the outdoor lighting that is controlled from within the dwelling units.

On the other hand, outdoor lighting for the overall building site must meet prescriptive wattage allowances in §170.2(e)6 plus mandatory lighting controls and acceptance testing requirements in §160.5(c) and (e).

The outdoor lighting for the overall site must also meet the prescriptive wattage allowance. The outdoor lighting for the overall building site consists of two pole lights at 35 watts each for a total of 70 watts. Since the prescriptively allowed hardscape lighting for the site is 386 watts, the site lighting complies with the Energy Code.

The figure below shows the outdoor lighting on the site as well as the lighting at the entry to the dwelling unit.

Figure 77: Garden Style Multifamily CASE Example: Outdoor Luminaires located on site (left); Dwelling Unit Entry Light and the entry switch on/off switch located inside the unit (right)

Image: IOU CASE Team

The table below provides an overview of the compliance to the mandatory and prescriptive requirements for this case study.

Table 11-67: Lighting of Garden Style Multifamily Building (Case Example 1)

Item: Dwelling Unit Lighting	Proposed Design	Applicable Mandatory Requirements	Applicable Prescriptive Requirements	Compliance Option
Luminaires (light fixtures)	All rooms: JA8 dimmable LED fixtures All fixtures are controlled by on/off switch plus dimmers.	§160.5(a)1 and 2.	Prescriptive: None	1.The proposed luminaires meet the efficacy requirements of Table 160.5-A. 2.Besides the efficacy requirements, there could be applicable luminaire related requirements depending on the luminaire types (screw based luminaires, recessed luminaires, and enclosed luminaires).
Bathroom Lighting	Bathrooms: Light in exhaust fan unit controlled with vacancy sensor	§160.5(a)1 and 2E.	Prescriptive: None	1.The proposed design meet the requirement of §160.5(a)2E. 2.The code requires at least one bathroom luminaire must be controlled by an occupancy sensor or vacancy sensor with automatic-off functionality. If there is a second luminaire installed in the bathroom, it is optional for the luminaire to meet
Entry Door Lighting outside the unit	One 25 watt LED light installed by the entry door to each residence unit, motion sensor and photocontrol plus on/off switch controlled from inside each dwelling unit.	1. Luminaire efficacy per Table 160.5-A. 2.§160.5(a)3A requires manual on/off combined with photocell plus motion sensor or auto time switch OR astronomical time clock.	Prescriptive: None	1.The proposed luminaire meets the efficacy requirements of Table 160.5-A. 2.The proposed photocontrol plus on/off switch and motion sensor control meet the requirements of §160.5(a)3A.

Table 11-68: Outdoor Lighting of Garden Style Multifamily Building (Case Example1 1)

Outdoor Lighting System	Proposed Design	Applicable Mandatory Requirements	Applicable Prescriptive Requirements	Compliance Approach/option
Outdoor Lighting Zone (LZ)	LZ2	LZ2 per Table 10-114-A for all multifamily project locations	Prescriptive: None	N/A
Outdoor Luminaires (fixtures)	Two 16 ft high light poles with one 35 watt, 90 lumen lamp per fixture.	Backlight, Uplight, and Glare (BUG) Shielding if ≥ 6,200 initial lumens. Lighting Controls: - Daylight Availability, - Motion Sensors if > 40 watts/fixture and within 24 ft of ground, - Automatic Scheduling	Hardscape area: 1,200 ft² General hardscape lighting allowance = 0.03 W/ft² x 1,200 ft² = 36 W Initial lighting Allowance = 350 W Total Allowance: 36 W + 350 W = 386 W	1.The luminaire BUG requirements do not apply to this lighting design as the luminaires are below the code trigger threshold on initial lumens. 2.The proposed outdoor lighting power is below the maximum allowed lighting power. Therefore, the proposed outdoor luminaires meet the code requirements.
Outdoor Lighting Controls	The light poles are controlled by programmable astronomical time clock. The entire site of 1,200 ft² hardscape including the outdoor lighting is operated by a property	Lighting Controls: - Daylight Availability, - Motion Sensors if > 40 watts/fixture and within 24 ft of ground, - Automatic Scheduling	Prescriptive: None	The motion sensors requirements do not apply to this lighting design as the luminaire rated wattage (35W) is below the code trigger threshold (40W). The proposed programmable astronomical time clock meets the

Outdoor Lighting System	Proposed Design	Applicable Mandatory Requirements	Applicable Prescriptive Requirements	Compliance Approach/option
	management firm.			daylight availability requirement and automatic scheduling requirement.
Verifications:	Outdoor lighting will have ATT verification for astronomical time clocks	Mandatory ATT for site lighting controls	Prescriptive: N/A	Outdoor lighting controls acceptance test is required.

Source: California Energy Commission

11.7.7.2 Case Example 2: A Five-story Mid-Rise Multifamily Building

This Mid-Rise Multifamily Case Study covers a new five-story multifamily building in Sacramento, California (Climate Zone (CZ) 12). This is a sample project created for training purposes, and it includes 112,044 ft² of conditioned floor area with 88 dwelling units, shared residential corridors, laundry rooms, fitness center and lounge, plus ground floor retail. The tables below provide details about the proposed lighting design and the possible compliance options for meeting the Energy Code which includes mandatory and prescriptive requirements for indoor and lighting outdoor lighting.

Table 11-69: Building Information about the Mid-rise Multifamily Building in CASE Example 2

General Information and Total Conditioned Floor Area	Applicable Lighting Code Requirements (mandatory)	Applicable Lighting Code Requirements (Prescriptive)
New five-story mid-rise multifamily building, 88 dwelling units, common use areas, ground floor retail, Sacramento, CA. Conditioned Floor Area (CFA) as follows:	§160.5(c) for outdoor lighting of the multifamily building site. §160.5(e) for sign lighting (indoor and outdoor).	§170.2(e)6: Outdoor lighting for overall site, new multifamily building ≥ four stories, Climate Zone (CZ) 12. §170.2(e)7 for sign lighting.
Dwelling Units: 78,384 ft²	§160.5(a)	None.
Multifamily Common Service Areas: 17,487 ft²	§160.5(b)	§170.2(e)1 thru 4.

General Information and Total Conditioned Floor Area	Applicable Lighting Code Requirements (mandatory)	Applicable Lighting Code Requirements (Prescriptive)
Nonresidential: 16,173 ft²	Requirements for lighting in nonresidential spaces in mixed use buildings are covered by nonresidential lighting requirements. (Refer to Chapter 5.)	Requirements for lighting in nonresidential spaces in mixed use buildings are covered by nonresidential lighting requirements. (Refer to Chapter 5.)
Total: 112,044 ft²	(blank space)	(blank space)

Source: California Energy Commission

Figure 78: Dwelling Unit Balcony Light for Case Example 2: Sideview of the Balcony Light with On/Off Switch Controls (left); Plan view of the Balcony Light On/Off Switch (right)

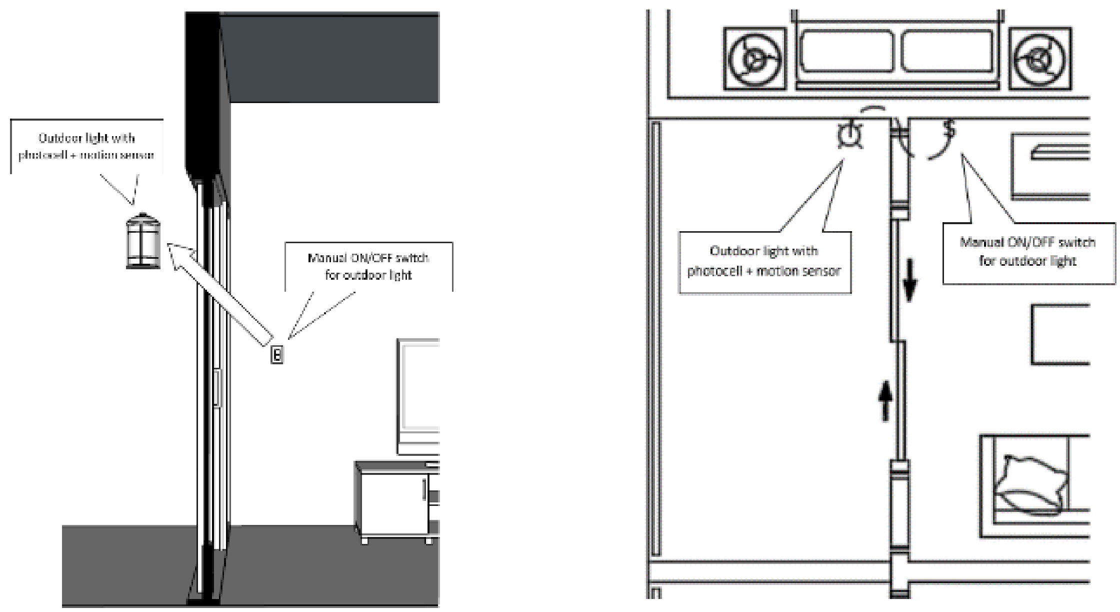


Table 11-70: Dwelling Unit Lighting for CASE Example 2

Outdoor Lighting System	Proposed Design	Applicable Mandatory Requirements	Applicable Prescriptive Requirements	Compliance Option
Dwelling Units: Indoor Lighting	All rooms: JA8 dimmable LED fixtures with on/off switch plus dimmers,	§160.5(a)1 and 2.	Dwelling Units: Indoor Lighting	All rooms: JA8 dimmable LED fixtures with on/off switch plus dimmers,
Dwelling Units: Outdoor Lighting	One 25 watt LED light installed next to the sliding glass door between the balcony and conditioned space for dwelling units with balconies on 3rd and 5th floors, occupancy sensor and photocontrol plus on/off switch controlled from inside each dwelling unit, Installed per §160.5(a)1 and 3	Luminaire Efficacy per Table 160.5-A,		Dwelling Units: Outdoor Lighting

Source: California Energy Commission

Table 11-71: Multifamily Common Service Area and Retail Indoor Lighting for CASE Example 2

Outdoor Lighting System	Proposed Design	Applicable Mandatory Requirements	Applicable Prescriptive Requirements	Compliance Option
MF Common Service Area: Indoor Lighting	Common service areas designed to meet prescriptive wattage allowances and mandatory controls	§160.5(b): Lighting Controls: - Manual On/Off - Multi-level - Automatic Shut Off - Automatic Daylighting -Demand Responsive Controls	Meet allowed wattage requirements of §170.2(e) for each space type	Mandatory: Yes Prescriptive: Yes
Retail: Indoor Lighting	Indoor lighting for retail spaces to comply with Prescriptive wattage allowances and Mandatory controls as tenant improvements on occupancy	§130.1: Lighting Controls: - Manual On/Off - Multi-level - Automatic Shut Off - Automatic Daylighting -Demand Responsive Controls	Meet allowed wattage requirements of §140.6 for each space type	Mandatory and Prescriptive compliance to be shown as tenant improvements under separate permit
Verifications:	Common service area lighting, retail indoor lighting will have ATT verification for lighting controls	Mandatory ATT for lighting controls	N/A	Mandatory: Yes Prescriptive: N/A

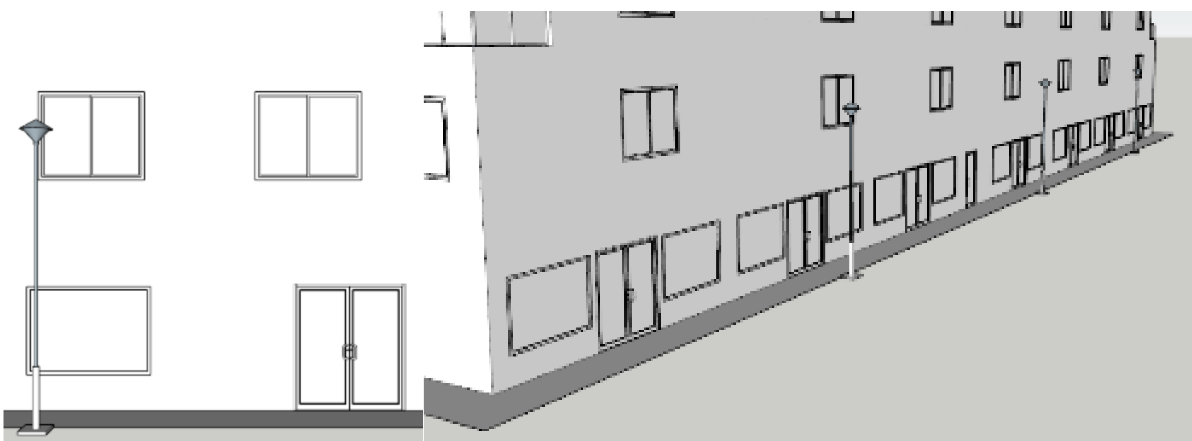
Source: California Energy Commission

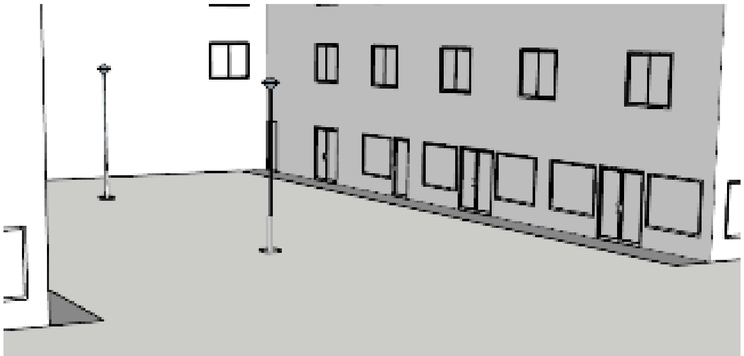
Table 11-72: Outdoor Lighting for CASE Example 2 – Proposed Design and Compliance Option

Outdoor Lighting System	Proposed Design	Applicable Mandatory Requirements	Applicable Prescriptive Requirements	Compliance Option
Site: Outdoor Lighting Zone (LZ)	LZ2	LZ2 per Table 10-114-A for all multifamily project locations	None.	
Site: Outdoor Lighting	Controlled by management and serves entire site, 7,274 ft² hardscape,	Site: Outdoor Lighting	Controlled by management and serves entire site, 7,274 ft² hardscape,	Site: Outdoor Lighting
Verifications:	Site lighting will have ATT verification for programmable astronomical time clock	Mandatory ATT for lighting controls	N/A	Mandatory: Yes

Source: California Energy Commission

Figure 79: Outdoor Lighting for CASE Example 2: Sideview of an Outdoor Luminaire at the Multifamily Building Site (top left); Outdoor Luminaires for Walkway Lighting (top right); Outdoor Luminaires for Courtyard Lighting (bottom)





This mixed use mid-rise building has separate indoor lighting requirements for the dwelling units compared to the multifamily common service areas and nonresidential retail spaces, and it also has different requirements for the outdoor lighting for the dwelling unit balconies versus the outdoor lighting for the building overall.

The lighting installed inside the dwelling units and the outdoor lighting that is controlled from within the dwelling units must comply with luminaire efficacy and mandatory lighting control requirements.

All of the proposed dwelling unit lighting has been designed to meet applicable mandatory requirements, so all the indoor and outdoor dwelling unit lighting complies with the Energy Code without any other requirements.

The outdoor lighting for the overall building site needs to comply with mandatory outdoor lighting controls, acceptance testing, and prescriptive outdoor requirements, and must also meet the prescriptive outdoor lighting power allowance requirements. The site lighting consists of nine pole lights at 35 watts each for a total of 315 watts. The prescriptively allowed hardscape lighting power allowance for the site is 568 watts, so the site lighting complies with the Energy Code.

Indoor lighting for the multifamily common service areas and nonresidential retail spaces must comply with mandatory indoor lighting control, acceptance testing, and prescriptive indoor lighting power allowance requirements. The prescriptive lighting power allowances for multifamily common service areas versus nonresidential retail spaces are very similar, but they are found in different sections of the Energy Code.

One common situation for retail spaces in buildings like this is that the lighting is not fully permitted or installed until new tenants move in.

11.8 Electrical Power Distribution

This section describes the Title 24, Part 6, Building Energy Efficiency Standards (California Energy Code or the Energy Code) requirements in §160.6 for energy efficiency features used for electrical power distribution systems in multifamily buildings. The requirements are mandatory and, therefore, are not included in the energy budget for the performance approach. The requirements of §160.6 apply to all newly constructed buildings and additions.

11.8.1 What's New for the 2022 Energy Code

There have been no significant changes for electrical power distribution systems in the 2022 update to the Energy Code.

11.8.2 Service Electrical Metering Requirements

§160.6(a)

All service electrical metering requirements are analogous to the corresponding code section for nonresidential buildings as applied to multifamily buildings. Please refer to Section 8.2 for a detailed discussion of the code language that applies to this section.

11.8.3 Separation of Electrical Circuits for Electrical Energy Monitoring

§160.6(b)

All separation of electrical circuits requirements are analogous to the corresponding code section for nonresidential buildings as applied to multifamily buildings. Please refer to Section 8.3 for a detailed discussion of the code language that applies to this section.

The separation of load is not required for the electrical distribution system that provides power to the dwelling units and has a separate meter for each unit.

11.8.4 Voltage Drop Requirements

§160.6(c)

All voltage drop requirements are analogous to the corresponding code section for nonresidential buildings as applied to multifamily buildings. Please refer to Section 8.4 for a detailed discussion of the code language that applies to this section.

11.8.5 Circuit Controls and Controlled Receptacles for 120-Volt Receptacles

§160.6(d)

All circuit controls and controlled receptacle requirements are analogous to the corresponding code section for nonresidential buildings as applied to multifamily buildings with the added clarification that this section applies to common use areas.

Receptacles in common use areas providing shared provisions for living, eating, cooking, or sanitation to dwelling units that would otherwise lack these provisions are exempt from the controlled receptacle requirements.

Dwelling units are exempt from these requirements. Please refer to Section 8.5 for a detailed discussion of the code language that applies to this section.

11.8.5.1 Demand Response

§160.6(e), §110.12(a)

All demand response requirements are analogous to the corresponding code section for nonresidential buildings as applied to multifamily buildings. Please refer to Appendix D for guidance on demand response for multifamily buildings.

11.8.6 Equipment Requirements – Electrical Power Distribution Systems

§110.11

All electrical power distribution system requirements are analogous to the corresponding code section for nonresidential buildings as applied to multifamily buildings. Please refer to Section 8.7 for a detailed discussion of the code language that applies to the selection of transformers for the building.

11.8.7 Additions and Alterations

§180.0

All additions and alterations requirements are analogous to the corresponding code section for nonresidential buildings as applied to multifamily buildings. Please refer to Section 8.6 for a detailed discussion of the code language that applies to this section.

11.9 Photovoltaic, Community Shared Solar, Battery Storage, and Solar Ready Buildings

This section describes the compliance requirements for solar photovoltaic (PV) systems, solar readiness, battery storage systems, and community-shared solar electric generation and/or storage systems for newly constructed multifamily buildings. For information about solar water heating system, please see Section 6.

Table 11-73 provides an overview of the location of the multifamily PV and battery storage requirements in the 2022 Energy Code and where descriptions reside in this document.

Table 11-73: Overview of Multifamily PV and Battery Requirements

	Mandatory Energy Code	Prescriptive Energy Code	Performance Energy Code	Compliance Manual Section
Solar PV	N/A	§170.2(f), §170.2(g), JA11	§170.1(b), JA11	11.9.2
Solar Ready	§160.8(a), §110.10	N/A	N/A	Chapter 9
Battery Storage	N/A	§170.2(h), JA12 (four or more habitable stories only)	§170.1(b), JA12	11.9.4
Community-shared Solar	N/A	N/A	§170.1(b), §10-115	11.9.5

Source: California Energy Commission

11.9.1 What's New for the 2022 Energy Code

The PV and battery storage installation are new prescriptive requirements in 2022 Energy Code for newly constructed multifamily buildings with four or more habitable stories. The prescriptive PV requirement sets the standard design budget for the performance approach. A definition for solar access roof area (SARA) was added to define the PV sizing requirement for multifamily buildings based on available unshaded roof area. As a result of the new definition of SARA and changes in Exception 1 to §170.2(f), previous exceptions were removed, and new exceptions added. There is a new exception for multifamily buildings unable to comply with ASCE Snow Load requirements with the addition of solar panels and other mounting equipment. For multifamily buildings with four or more habitable stories, an exception based on availability of virtual net energy metering or community shared solar is added to avoid the added costs of direct wiring to individual tenant spaces.

Changes to community solar requirements include clarification of additionality requirements, opt-out requirements, and a new section for maximum size for community scale system. There is also a new annual reporting requirement and a public review process for local adoption of public agencies administering community shared solar PV and/or battery storage system.

11.9.2 Photovoltaic System

This section describes the prescriptive PV requirements for multifamily buildings, performance approach compliance and the Joint Appendix 11 requirements for orientation, shading, solar access verification, remote monitoring capability and interconnection requirements.

11.9.2.1 Prescriptive Requirements

§170.2(f), 170.2(g)

Solar PV sizing, installation, and enforcement requirements vary for buildings of up to three habitable stories and four or more habitable stories. JA11 requirements apply to all multifamily buildings.

The prescriptive PV size is calculated using either 1) an equation based on conditioned floor area or 2) solar access roof area (SARA).

SARA includes any roof space on newly constructed buildings, including covered parking areas and carports that can support a PV system per Title 24 Part 2 Section 1511.2, and has 70 percent or greater annual solar access. It does not include occupied roof areas as specified by CBC Section 503.1.4. SARA does not include roof area that is otherwise required to comply with other building code requirements if confirmed by the Executive Director.

Annual Solar Access is calculated by dividing the total annual solar insolation accounting for shading obstructions by the total annual solar insolation if the same areas were unshaded by obstructions. Annual solar access is determined by a qualified solar assessment tool meeting JA11.4 requirements, explained further in the Solar Access Verification section below.

$$\text{Solar Acccess} = \frac{\text{Solar Insolation including Shading}}{\text{Solar Insolation without Shading}}$$

Shading obstructions to be considered for solar access calculations include:

- For steep slope roofs in buildings up to three habitable stores, existing permanent natural or manmade obstructions, such as trees, hills, adjacent structures, that are external to the building.
- For buildings with four or more habitable stories and buildings up to three habitable stories with low-sloped roofs, all obstructions including those that are external to the building and obstructions that are part of the building design and elevation features

B. Up to Three Habitable Stories

Multifamily buildings with up to three habitable stories are required to have a PV system installed unless the building qualifies for an exception. The minimum qualifying PV system size is calculated as a minimum of,

- Projected annual electrical usage as described by the Equation 11-3 below or
- Maximum PV system size that can be installed in SARA

Equation 11-3

kWPV required = (CFA x A)/1000 + (N_{DU} x B)

WHERE:

kWPV = kWdc size of the PV system

CFA = Conditioned floor area

N_{DU} = Number of dwelling units

A = CFA Adjustment factor from Table 11-74

B = Dwelling unit adjustment factor from Table 11-74

Table 11-74: CFA Adjustment Factor

Climate Zone	A - CFA	B - Dwelling Units
1	0.793	1.27
2	0.621	1.22
3	0.628	1.12
4	0.586	1.21
5	0.585	1.06
6	0.594	1.23
7	0.572	1.15
8	0.586	1.37
9	0.613	1.36
10	0.627	1.41
11	0.836	1.44
12	0.613	1.40
13	0.894	1.51
14	0.741	1.26
15	1.56	1.47
16	0.59	1.22

Source: California Energy Commission

11.9.3 Photovoltaic System Exceptions –Low-rise Multifamily

There are five allowable exceptions to the prescriptive PV requirements for multifamily buildings with up to three habitable stories as listed below.

- No PV system is required if the SARA is less than 80 contiguous sq. ft. For steep slope roofs, SARA must not consider roof areas with a northerly azimuth that lies between 300 degrees and 90 degrees, from true north.
- No PV system is required if the minimum PV system size specified by §170.2(f) is less than 1.8 kW_{dc}.

- No PV system is required if it is not possible for the PV system, including panels, modules, components, supports, and attachments to the roof structure, to meet the requirements of the American Society of Civil Engineers (ASCE), Standard 7-16, Chapter 7, Snow Loads.
- No PV system is required if buildings are approved by the planning department prior to January 1, 2020. SARA can be determined using shading designs from the approval process demonstrating the roof areas that are now allowed to have PVs. It does not require an additional solar assessment to determine SARA per 2022 Title 24 requirements.
- The required PV sizes from Equation 11-3 may be reduced by 25 percent if a battery storage system is installed. The battery storage system must have a minimum usable capacity equivalent to 7.5 kWh and meet the qualification requirements specified in Joint Appendix JA12.

11.9.3.1 Four or More Habitable Stories

Multifamily buildings with four or more habitable stories also require a newly installed PV system. See chapter 9 for the prescriptive and performance requirements for buildings with more than three habitable stories.

11.9.3.2 Stepwise Guide for Compliance

The prescriptive compliance approach for solar PV system is summarized in Table 11-75, which provides the appropriate sequence of steps that identifies if the PV system's installation is triggered and the corresponding requirements to comply with the prescriptive approach. The requirements verify that the roof has enough appropriate roof space, with no obstruction and adequate structural strength.

Table 11-75: Guide to Solar PV Prescriptive Requirements

Step	Three or fewer stories	Four or more stories
Check for Virtual Net Energy Metering feasibility*	N/A	If program is not available, PV is not required
Calculate SARA using approved solar assessment tool	SARA determines the maximum bound of prescriptive PV size requirement.	SARA determines the prescriptive PV size requirement. If SARA is less than 3%, no PV is required.
Check contiguous SARA	If SARA is less than 80 contiguous ft., no PV is required.	If SARA is less than 80 contiguous ft., no PV is required.

Step	Three or fewer stories	Four or more stories
Calculate prescriptive PV size using both equation and SARA approach	Minimum of PV size calculated per Eq 11-3 and maximum possible PV in available SARA.	Minimum of PV size calculated per Eq 11-4 and SARA*14W/ft^2.
Check equation calculated PV size is more than minimum requirement	If PV size is less than 1.8kW, PV is exempted.	If PV size is less than 4kW, PV is exempted.
Check snow load design per ASCE 7-16**	If the roof cannot support the required PV structure per snow load design, PV is exempted.	If the roof cannot support the required PV structure per snow load design, PV is exempted.
Check for battery installation plan	If a minimum of 7.5kWh battery storage system is installed complying with JA12 requirements, PV size (From step 4) can be reduced by 25%.	N/A
Prepare documentation		

Source: California Energy Commission

*If VNEM is not feasible for multiple tenant buildings, solar PV is not required.

**For regions expecting heavy snowfall, snow loads need to be considered in structural design calculations and possible interference to solar access can occur.

Example 11-45: PV size calculation for three habitable stories or less

Question:

How is the prescriptive PV size calculated for a multifamily building with two habitable stories of 7,000 sq. ft. and eight dwelling units in Climate Zone 3?

Answer:

Follow steps 1 to 3 from Table 11-75 to ensure that the multifamily building does not qualify for an exception. The prescriptive size in step 4 is calculated using the two approaches below,

Applying Equation 11-3,

CFA = 7,000

N_{DU} = 8

A = CFA Adjustment factor from Table 11-74 = 0.628

B = Dwelling unit adjustment factor from Table 11-74 = 1.12

kW_{PV} required = (CFA x A)/1000 + (N_{DU} x B)

= (7,000 x 0.628)/1000 + (8 x 1.12)

= 4.396 + 8.96

= 13.4

Therefore, prescriptive PV size calculated per equation approach is 13.4 kW.

Check maximum allowable PV in the available SARA,

Assuming 50% of roof space is available for installing solar panel, which is calculated to be 0.5x3,500 = 1,750 ft^2.

Assuming a typical size of solar panel to be 20 ft^2. and allowing a margin of area around the solar panel, an approximate of 58 panels can be fit into the available SARA. This would roughly calculate to a PV size of 14.5 kW.

The PV size that can be accommodated in available SARA is bigger than the size of 13.6kW calculated using the Equation 11-3. Hence, the prescriptive size is calculated to be 13.6kW.

Example 11-46: PV size calculation for four or more habitable stories

Question: How is the prescriptive PV size calculated for a multifamily building with ten habitable stories, 125,400 ft^2. and 117 dwelling units in Climate Zone 3?

Answer:

Follow steps 1 to 3 from Table 11-75 to ensure that the multifamily building does not qualify for an exception. The prescriptive size in step 4 is calculated using the two approaches below:

i. Applying Equation 11-3,

CFA = 125,400

A = CFA Adjustment factor from Table 11-3= 1.82

kW_{PV} required = (CFA x A)/1000

= (125,400 x 1.82)/1000

= 228.2 kW

Therefore, prescriptive PV size calculated per equation approach is 228.2 kW.

ii. Applying SARA approach,

SARA calculated per solar assessment tool, described in JA11, is multiplied by 14W/ft^2 to determine the prescriptive PV size.

Assuming 30% of roof space (12,540 $ft^2$to qualify to be SARA, then the prescriptive PV size calculated using SARA approach is,

= 0.3 x 12,540ft^2 x 14 W/ft^2

= 52,668 W

= 52.7 kW

The prescriptive PV size is calculated to be a minimum of PV sizes calculated using both approaches,

= MIN (228.2,52.7)

= 52.7 kW

=

The PV size that can be accommodated in available SARA is smaller than that calculated using the Equation 11-3. Hence, the prescriptive size is calculated to be 52.7kW.

11.9.3.3 Joint Appendix 11 (JA11) Requirements

The installed PV system for any multifamily building must meet the applicable requirements specified in JA11 for both the prescriptive and performance approach. Requirements include considerations such as system orientation, shading criteria, solar access verification, remote monitoring, and interconnection requirements.

11.9.3.4 System Orientation

For prescriptive compliance, if a PV system is installed with a pitch greater than 2:12 or 10 degrees, the arrays must be oriented between 90 to 300 degrees from true north. If the pitch is less than 10 degrees, the orientation has insignificant impact on the array's performance; therefore, the PV system can be installed with any azimuth range.

Using the performance approach, the PV array may be oriented (and modeled) in any direction, including due north; however, the more the orientation deviates from the southwest optimum, the worse the system performs, resulting in a larger PV system size to meet the same load.

The California Flexible Installation (CFI) is a simplified modeling option in the performance approach. This option allows flexibility, and it has no specific requirements on orientation and tilt, while meeting the minimum shading criterion outlined in JA11.3.1. To use the CFI option for compliance:

- For CFI1, the PV array azimuth angle must be anywhere between 150 to 270 degrees from true north, and the tilt of all PV modules must be the same as the roof for pitches up to 7:12.
- For CFI2, the PV array azimuth angle must be anywhere between 105 to 300 degrees from true north, and the tilt of all PV modules must be the same as the roof for pitches up to 7:12.

11.9.3.5 Shading

The PV system should eliminate or avoid shading from any obstruction to the array Obstructions include the following:

- Any vent, chimney, architectural feature, mechanical equipment, or other obstruction that is on the roof or any other part of the building.
- Any part of the neighboring terrain.
- Any tree that is mature at the time of installation of the PV system.
- Any tree that is planted on the building lot or neighboring lots or planned to be planted as part of landscaping for the building. (The expected shading must be based on the mature height of the tree.)
- Any existing neighboring building or structure.

- Any planned neighboring building or structure that is known to the applicant or building owner.
- Any telephone or other utility pole that is closer than 30 ft. from the nearest point of the array.

Any obstruction located directly north of the array does not count as shading obstruction.

For prescriptive compliance, the weighted average of annual solar access, determined by solar access verification tool approved per JA11.4 requirements, across each solar panel must be at least 98 percent. The individual roof areas that constitute SARA must be greater than 70 percent per its definition. This requirement assumes that SARA is more than 80 contiguous sq. ft. and that the exception 1 to section 170.2(f) does not apply. If the annual solar access is less than 98%, then the building does not meet the prescriptive requirement and the performance compliance method must be used instead.

For the performance approach, the annual solar access is a required input and there is no minimum requirement for annual solar access. However, shading on the PV array must be avoided to get maximum benefit to meet the TDV energy.

For more information on software inputs, please refer to the software user's manual.

Example 11-47: Shading

Question:

What impact does shading have on the solar PV sizing requirement?

Answer:

Prescriptively the PV array cannot have any shading and must meet the minimum shading criteria in JA11. Under the performance path the shading condition must be modeled, and it will result in a larger PV size that meets the same TDV budget as a smaller unshaded PV system.

Example 8-4: Shading

Question:

How are the shading requirements of JA11.3 verified using prescriptive compliance approach?

Answer:

- Assess SARA using solar access verification tool as required by JA11.4.1
- If SARA is greater than 80 contiguous sq. ft., assess annual solar access for each solar panel
- Take weighted average of annual solar access across each solar panel
- Verify if the weighted average of annual solar access at each solar panel is greater than 98%. If yes, then the shading requirements of JA11.3 are met.

11.9.3.6 Solar Access Verification

A solar assessment tool that is certified by the Executive Director and complies with JA11.4.1 requirements must be used to document and verify the shading conditions of the PV system. The results of the solar access verification tool should be used to demonstrate compliance with:

- Prescriptive approach of at least 98% weighted average of solar access across all solar panels per JA11.3.1
- Performance approach of actual shading condition modeled in compliance software and indicated on certificate of compliance
- Exceptions related to SARA, Exception 1 of greater than 80 contiguous sq. ft. in §170.2(f) and greater than 3% of roof area in §170.2(g).

The CEC approved solar assessment tools can be of one of the following types:

- Physical tool that measures the availability of solar energy on installation site
- Software tool that models the physical features of the building and surrounding shading conditions including roofs and trees, and then calculates their solar potential by analyzing it against historical weather data
- Satellite or drone imaging data if it can demonstrate solar access percentages similar to on-site measurements

Table 11-76 summarizes the solar access verification tool requirements from JA11.4.1.

Table 11-76: Solar Access Verification Tool Requirements

Category	**Requirements**
Input	Physical features of building Obstructions to the roof listed in Section 0: Shading above per JA11.3 Historical weather data
Calculations	Calculate annual solar access percentage of each individual solar array. Calculate annual solar access percentage as a weighted average of the whole. Include all obstructions, including any tree that is planted on the building lot or neighboring lots or planned to be planted in landscaping. Not to include horizon shading in the calculation
Reporting	Produce a shade report with a summary of the PV system, including the address of the project, individual array panel count, orientation, annual solar access percentage, and weighted average of the PV system as whole.

Source: California Energy Commission

11.9.3.7 System Monitoring Requirements

The PV system must be integrated with a monitoring system that can provide remote monitoring capability to its user. The monitoring data should be accessible via a web-based portal or mobile device application that enables the building manager, owner, or occupants to monitor the performance of their PV system. This data can be useful to identify, report, and correct performance issues with the panels, inverters, shading, or other issues that may adversely impact the performance of the PV system. At a minimum, the building manager, building owner, or occupants must have access to the following information:

- The nominal kW rating the PV system.
- Number of PV modules and the nominal watt rating of each module.
- Hourly (or 15-minute interval), daily, monthly, and annual kWh production in numeric and graphic formats for the system.
- Running total of daily kWh production.
- Daily kW peak power production.
- Current kW production of the entire PV system.

Example 11-48 Remote Monitoring

Question:

How do I implement monitoring to meet section JA11.5.1 including the current reading?

Answer:

There are multiple options. Many inverters can connect via ethernet and wirelessly to the building manager's, building owner's, or occupant's internet, and others use independent cellular connections. For cellular, the data should be updated to the monitoring portal periodically as allowed by the cellular plan.

11.9.3.8 Interconnection Requirements

The installed inverters must be tested in accordance with the applicable requirements in UL1741 and UL1741 Supplement A.

The PV system and the associated components, including the inverters, must comply with the California Public Utilities Commission (CPUC) Electric Tariff Rule 21, which governs CPUC-jurisdictional interconnections for all net energy metering customers. Rule 21 requires that inverters have certain capabilities to ensure proper operation of the electrical grid as more renewables are interconnected. The inverters must perform functions that, when activated, can autonomously contribute to grid support during excursions from normal operating voltage and frequency system conditions by providing dynamic reactive/real power support, voltage and frequency ride-through, ramp rate controls, communication systems with ability to accept external commands, and other functions.

11.9.3.9 Compliance and Enforcement

To certify that the PV system complies with all JA11 requirements, the installer must provide:

- Certificate of Installation for PV system that all provisions of JA11 are met. The certificate of installation must be available on the building site for inspections.
- **Solar Assessment Report:** Solar assessment report produced by a CEC approved solar access verification tool to verify the shading conditions that all requirements pertaining to SARA are met. If satellite, drone, or other digital image is used for solar access verification, the solar assessment report must be created or dated after the installation of the PV system. If the digital image is dated before the installation of PV system, additional on-site pictures must be attached to clearly show that the installed system matches the system modeled in the solar assessment report.

The local enforcement agency must verify that the Certificate of Installation is valid complete and correct, and uploaded into a Commission-approved registry.

11.9.4 Solar Ready

§110.10

Solar ready requirements are mandatory for newly-constructed multifamily buildings with fewer than 10 habitable stories that do not have a photovoltaic system installed. These requirements are explained in Chapter 9.

11.9.5 Battery Storage System

Multifamily buildings with four or more habitable stories are required to have battery storage under the prescriptive approach if solar PV is installed and meets the prescriptive requirements. The battery system can also be installed as a stand-alone system for additional compliance credit. The battery storage system is required to meet the qualifications of Joint Appendix JA12 for both prescriptive and performance approach. For multifamily buildings with 3 or less habitable stories, battery storage is not required and is available as compliance credit under the performance compliance approach.

The primary function of the battery storage system is load shifting to harmonize the onsite PV system with the grid and deliver benefits to the environment, building owner, and building occupants.

11.9.5.1 Prescriptive Requirements

§170.2(h)5

All buildings that are required by §170.2(g) to have a PV system must also have a battery storage system meeting the minimum qualification requirements of

§170.2(h) and Reference Joint Appendix JA12. Reference chapter 9 of this manual for the prescriptive battery storage requirements.

11.9.5.2 Performance Approach

§170.1(b)

C. Energy Budget Calculation

Battery storage system is added to the list of compliance loads in the 2022 Title 24 energy budget per the §170.1. The TDV energy budget is calculated by the software as the sum of all building loads, including PV and the battery storage system, in addition to space conditioning, indoor lighting, mechanical ventilation, service water heating, and covered process loads.

The TDV energy budget can also be met partially or fully by connecting the building to a community battery storage system that complies with Title 24, Part 1, §10-115. The requirements of community shared storage system compliance pathway are detailed in Section 11.11.4 below.

11.9.5.3 Exceptions to Battery Storage Requirements

Exception 1 of §170.2(h) from the prescriptive requirements can also be used under the performance approach. Multifamily buildings with installed PV less than 15 percent of the prescriptive size calculated by the equation 11-5 and 11-6 are exempt from installing battery storage. The building permit applicant must select the appropriate exception in the software and provide documentation to the building department with the building permit application.

11.9.5.4 Additional Requirements

The battery storage system must comply with all the applicable requirements of Joint Appendix 12 (JA12) reference standard as described in Section 11.11.3.3.

11.9.5.5 Joint Appendix (JA 12) Requirements.

The battery storage system must meet all applicable requirements in JA12, listed in chapter 9 of this manual, and be self-certified to the CEC by the manufacturer as a qualified product. The list of qualified JA12 products can be found here: https://www.energy.ca.gov/programs-and-topics/topics/rnewable-energy/solar-equipment-lists

Coupling a PV system with a battery storage system and appropriate control strategy will allow for a smaller PV system than otherwise would not have been possible.

11.9.6 Community Shared Solar Electric Generation and Storage System

§170.1(b)

A community-shared solar electric generation system, other renewable electric generation system, and/or community shared battery storage system may offset part or all the solar electric generation system time dependent valuation (TDV) energy required to comply with the standards. This compliance pathway under the performance approach should provide dedicated power, utility energy reduction credits to the permitted building and is approved by the Energy Commission as specified in Title 24, Part 1, Section 10-115.

Community Shared Solar Electric Generation means solar electric generation or other renewable technology electric generation that is installed at a different site.

Community Shared Battery Storage refers to the battery storage systems installed at a different site, separately or in combination with Community Shared Solar Electric Generation.

The community shared systems should be approved by Commission and be available for inspection by enforcement agency during compliance verification process.

11.9.6.1 Qualification Requirements

The Community Shared Solar Electric Generation system should meet the following requirements discussed below.

D. Enforcement Agency

The Community Shared Solar Electric Generation system and/or Community Shared Battery Storage system must exist and be available for enforcement agency review early in the permitting process, and it must not cause delay in the enforcement agency review and approval of the building that will be served. The enforcement agency should have jurisdiction and facilitated access to the Community Shared Solar Electric Generation system to verify the validity and accuracy of compliance documentation. All documentation required to demonstrate compliance for the building for Community Shared Solar Electric Generation system and/or Community Shared Battery Storage system must be completed prior to the building permit application.

11.9.6.2 Energy Performance

Energy Commission approved compliance software must be used to show that the energy performance of the building’s share of the Community Shared Solar Electric Generation system is equal to or greater than the partial or full offset claimed for the solar electric generation and battery storage system, which would otherwise be required for the building to comply with the Standards.

The minimum community shared solar size dedicated to the building and the annual kWh equivalence may be measured in one of two ways: 1) Using the CBECC Simplified approach for PVs and the CFI orientation option, or 2) by modeling the actual attributes of the system using the detailed approach. When the detailed approach is used, the compliance software will determine a minimum kW size that will represent the portion of the community solar resource dedicated to the building, based on PV system component performance characteristics, azimuth, inverter type, tracking versus fixed systems, climate zone, and CEC weather files containing solar availability data.

Additionally, If the community shared solar resources are coupled with a community shared battery storage system in the CBECC-Com, the modeled PV system must also be coupled with at least a battery storage system to determine the size share of the community solar resource dedicated to the building. Also, the portion of the community shared battery storage system dedicated to the dwelling must match the battery storage size modeled in CBECC software.

11.9.6.3 Participating Building Energy Savings Benefits

A specific share of the Community Shared Solar Electric Generation system, determined to comply with the energy performance requirement, must be dedicated on an ongoing basis to the building. The energy savings benefits allocated to the building must be provided in one of the following ways:

- Actual reductions in the energy consumption of the participating building
- Energy reduction credits that will result in virtual reductions in the building's energy consumption, including but not limited to generation credit, solar charge, program charge, and power charge indifference adjustment charge
- Payments to the building that will have an equivalent effect as energy bill reductions that would result from one of the other two options above

For all three options, the reduction in energy bills resulting from the share of the Community Shared Solar Electric Generation system dedicated to the building must be greater than the added cost that is charged to the building to obtain that share of the Community Shared Solar Electric Generation system and/or battery storage system.

11.9.6.4 Durability, Participation, and Building Opt-out

1. Durability

   The benefits from the specific share of the Community Shared Solar Electric Generation system and/or Community Shared Battery Storage system must be provided to each participating building for a period of at least 20 years.

   A. Participation

   The administrator(s) approved by the Energy Commission pursuant to Section 10-115(b)1, of community shared solar and/or community battery storage system should ensure that the "participation period" for all the participating building is 20 years regardless of the ownership of the building. However, the building owner can opt out of the community shared solar electric generation and/or community shared battery storage system if they install an on-site solar electric generation system and follow interconnection requirements pursuant to the opt-out requirements in Building Opt-Out section below. To demonstrate compliance, administrator(s) are required to fulfil one of the two options below.

- Equitable Servitude
    - The participating builders must impose an equitable servitude through a properly recorded declaration of covenants, conditions, and restrictions or other properly recorded covenant, deed restriction or other legally binding method referenced in each deed transferring title for each participating building.
    - This equitable servitude must obligate the original owner(s)/tenant(s) and all subsequent owner(s)/tenant(s) of the participating building to maintain the building's participation in the community shared solar and/or community shared battery storage system for the participation period or ensure installation and interconnection of an on-site solar electric generation system that satisfies the opt-out requirements.
    - The builder must ensure that the equitable servitude provides Commission-approved administrator the right to enforce the above provisions.
    - The equitable servitude must remain in force for a period of 20 years from the date of first participation of the building in the community shared solar and/or battery system.
    - The equitable servitude must not be revocable.
    - The equitable servitude must be delivered to all responsible parties through transfer disclosure statements.
- Other System
    - The Commission may approve another program, structure, or system by which an administrator (or other entity approved by the Commission) ensures the participation requirements of Section 10-115(a)4B will be satisfied for a participation period of no less than 20 years.

B. Compliance Documentation

This section determines requirements for administrator(s) to comply with record maintenance of compliance documents.

- The administrator must maintain record(s) of the compliance documentation that determined the requirements for the on-site solar electric generation system and/or battery storage system, which is in effect at the time the builder applied for the original building permit, and it establishes participants' obligations to meet the opt-out requirements.

- The administrator must provide a copy of this compliance documentation upon a participating building owner's request to every new owner of a participating building, when the administrator is notified that title has transferred.
- The administrator must provide a copy of this compliance documentation to any participating building owner who requests to opt-out.

C. Building Opt-Out

At any time during this period, the building owner must have the option to discontinue participation in the community shared solar and/or battery storage system if the building satisfies the opt-out requirements.

- Prior to opt-out, the building owner must demonstrate an on-site solar electric generation system to be installed, which meets the requirements of §170.0(a)3, which were in effect at the time the building was permitted.
- Prior to opt-out, the building owner should provide documentation from the installer of the on-site solar system or an attestation of the building owner with supporting documentation along with taking responsibility of all costs associated with it.
- The administrator must compare the opt-out documentation received from building owner to the original compliance documentation specified in Section 10-115(a)4C. Based on the opt-out documentation, the administrator must provide written confirmation that the installed solar system meets or exceeds the opt-out requirements within 30 days of receiving from building owner.
- The administrator may, at its discretion, verify the documentation through a physical inspection.
- The administrator must maintain record of the documentation that demonstrates and confirms the on-site solar generation system met the opt-out requirements for the remainder of the participation period.
- Upon the building owner's exercise of the opt-out, all costs and benefits associated with participation in the community shared solar and/or battery storage system must cease. If any balance of costs or benefits is owed to either party at the time of opt-out, such balance must be paid to that party.
- The administrator (or other entity approved by the Commission pursuant to Section 10-115(a)4Bii) must not impose any penalty related to a participating building's opt-out or charge participants for recuperation of

unrealized revenue that would have been expected to accrue beyond the end of participation. If the administrator (or other entity approved by the Commission) plans to charge any other fees at the time of building opt-out, the Application for Commission Approval must explain the purpose of those fees.

11.9.6.5 Additionality

The specific share of the Community Shared Solar Electric Generation System must provide the benefits to the participating building that are in no way made available or attributed to any other building or purpose. Renewable Energy Credits that are unbundled from the Community Shared Solar Electric Generation System do not meet this additionality requirement.

- The participating building(s) must be served primarily by renewable resources developed specifically for the community solar electric generation system.
- Other renewable resources may be used when participating buildings are permitted before the renewable resources developed for the program start operating or after they cease operating. During these times, other renewable resources may be used to meet the requirements of Section 10-115(a)4 for each participating building.
- The renewable resources, including those developed primarily to serve participating buildings and those utilized to fill before and after time gaps for the purpose of meeting the requirements of Section 10-115(a)4, must meet the following requirement:
    - For each renewable resource used to serve participating buildings, bundled (Product Content Category 1) Renewable energy credits (RECs) must be retired and tracked in the Western Renewable Energy Generation Information System on the behalf of program participants, to ensure that they will not be allocated to or used for any other purpose, including Renewable Performance Standard compliance, resale of RECs or renewable generation to any other person or entity, or any other mandatory or voluntary renewable electricity program requirement or claim.
- Renewable resources developed to serve participating buildings may also be used to serve other loads when there is excess generation beyond what is needed to serve participating buildings. Any excess generation used for such other loads must be isolated from the generation serving participating buildings and must not result in violation of Section 10-115(a)5C.

Example 11-51

Question

To help entities that might want to apply to the Energy Commission for approval of a Community Shared Solar Energy Generation System, please provide examples of each of the three optional ways energy savings benefits could be provided to comply with Participating Building Energy Savings Benefits requirements.

Answer

Examples would include:

Actual reductions in the energy consumption of the building: This could be accomplished by locating the PV systems for several houses on a carport on common land in a subdivision, and direct wiring the unique PV panels serving each house to an inverter that is located on the home's site. For homes served by utilities that are subject to compliance with Net Energy Metering requirements, the common land that is hosting the PVs on the carport would have to be adjacent to (could be directly across a street) the houses that are being served by the PV system. All other requirements of Section 10-115 would have to be met.

Utility energy reduction credits that will result in virtual reductions in the building's energy consumption that is subject to energy bill payments: This could be accomplished through a community shared solar program administered by a utility (like the Green Tariff Shared Renewables, or GTSR), for which a remote renewable resource is paid for through shares purchased for each home, and energy bill credits are that reduce monthly electricity bills are allocated based on the homes' shares, including but not limited to generation credit, solar charges, program charges, and nonparticipant charges. All other requirements of Section 10-115 would have to be met.

Payments to the building that will have an equivalent effect as energy bill reductions would result from one of the two options above: This could be accomplished by builders installing PV systems on other properties they own to offset the compliance requirement for onsite PVs on homes, they build. The homes would pay for a share of the PV systems on the other properties. The builders would be obligated to make an ongoing cash payment back to the homes for the home's share of the electricity generation achieved by the PV systems on the other properties. The share of the ownership of the PV systems on the other properties and the corresponding sharing of the electricity generation achieved by the PV systems on the other properties would not be accounted for through a utility system – the ownership share would not be paid to the utility and the payment for the share of the electricity generation achieved by the PV systems on the other properties would not be provided through a utility bill. The entire program would be administered by the builder for a 20-year period for each home. All other requirements of Section 10-115 would have to be met.

Example 11-52

Question

Explain what the cost requirements in Participating Building Energy Savings Benefits section above that says: "In other words, a building that participates in an approved community solar program cannot be charged more than the nonparticipating building that has no onsite PV system and does not participate in a community shared solar electric generation and/or battery storage program."

Answer

Regardless of the three options above is chosen, it must be cost effective to the home for the home to participate in a community shared solar electric generation system program. The home will pay for its share of the community renewable resource, and will receive either energy bill reductions, credits or cash payments for the electricity that is generated by the community renewable resource. The $ value of the bill reductions, credits or cash payments must exceed the cost to the home to pay for its share of the community renewable resource.

Let's take a hypothetical example of a Green Tariff Shared Renewables Program (GTSR) that is required by statute to be operated by the IOUs. The following shows the costs that the program charges a home to obtain shares of the program's community solar resources, and the energy bill credit. The charges and credit are allocated per KWh generated by the home's share of the community renewable resource.

Example Green Tariff Shared Renewables Program Details

Solar Charge	6.48 cents per kWh
Program Charge	2.956 cents per kWh
Power Charge Indifference Adjustment (PCIA) Charge	3.346 cents per kWh
Total Program Charges	12.782 cents per kWh
Generation Credit	-10.78 cents per kWh

The total cost that the home pays per kWh for its share of the community renewable resource is 12.8 cents per kWh and the energy bill credits for generation from the home's share of the community renewable resource is 10.8 cents per kWh. Since the value of the home's energy bill credit does not exceed the cost for the home to participate in the community solar program, the cost requirement is not met. Cost requirements can be brought into compliance through a combination of an increase in the generation credit and reductions in solar charge, program charge, and power charge indifference adjustment (PCIA) charge. In this example, if the generation credit raises by one cent, up to 11.8 cents, and combined charges decrease by 1.1 cents, down to 11.7 cents, then the program meets the cost requirements.

11.9.7 Code in Practice

11.9.7.1 Garden Style Multifamily Case Study

The Garden Style Multifamily Case Study considers a new two-story garden style multifamily building in Burbank, California (Climate Zone 9). This is a sample project created for training purposes, and it consists of 7,216 ft² of conditioned floor area with eight dwelling units and no common use areas. The case study tables in this chapter compare the proposed building solar electricity and battery storage to mandatory and prescriptive Energy Code requirements and evaluate possible compliance options.

Table 11-77: Garden Style Multifamily Case Study Compared to Mandatory and Prescriptive Renewable Energy Requirements (Climate Zone 9)

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Multifamily Building	New two-story garden style multifamily building, eight dwelling units, no common use areas, Burbank, CA	Section 110.10	Section 170.2(f), Joint Appendix JA11 New multifamily building ≤ three stories, Climate Zone (CZ) 9	Case study Mandatory and Prescriptive compliance rated for each feature below as "Yes" (complies), "No" (does not comply) or "N/A" (not applicable). If "No", see compliance options provided.
Total Conditioned Floor Area (CFA)	7,216 ft²		7,216 ft²	
PV System Electrical Output (kWdc)	15.6 kWdc	N/A	kWpv calculated per Equation 170.2-C: ≥ 15.3 kWdc	Mandatory: N/A Prescriptive: Yes
PV Panel Tilt	3:12 Pitch	N/A	Any PV with ≥ 2:12 pitch is defined as steep-sloped and must meet applicable orientation requirements	Mandatory: N/A Prescriptive: Yes
PV Panel Orientation	180 degrees (due South)	Section 110.10(b)	Section 170.2(f), JA11 PV for steep-sloped roofs must be installed between 90 degrees (due east) and 300 degrees (30 degrees north of due west)	Mandatory: Yes Prescriptive: Yes
Battery Storage	None	N/A	Not required for new multifamily buildings ≤ three stories	Mandatory: N/A Prescriptive: No

Source: California Energy Commission

Providing electricity generated using solar photovoltaics (PV) is a prescriptive requirement for multifamily buildings with three or fewer habitable stories. The minimum kWdc PV output capacity is the smaller of that calculated using Equation 170.2-C or the maximum that can be installed on the building's Solar Access Roof Area (SARA). SARA includes all of the building's unobstructed roof area (including garage roofs and other roofs on-site) with at least 70 percent solar access and structurally capable of supporting a PV system.

Figure 80: Garden Style Multifamily Case Study: Photovoltaics (PV) on South-Facing Roof

The total roof area for this case study including overhangs is 4,284 ft² measured in plan view and 4,416 ft² accounting for the 3:12 roof pitch. Half of the roof faces due south (180 degrees) and half faces due north (0 degrees). PV for steep-sloped roofs must be installed at orientations between 90 degrees (due east) and 300 degrees (30 degrees north of due west), so only the south-facing roof meets prescriptive orientation requirements. The south-facing roof has no obstructions and nothing shading it, so the SARA equals 2,208 ft².

The proposed PV system has 60 solar panels at 260 watts each or 15.6 kWdc. The total area of the panels is 1,056 ft² or less than half the SARA.

The minimum electrical output of the PV system calculated using Equation 170.2-C is:

kWpv= (CFA x A)/1000 + (N_{Dwell} x B).
kWpv = kWdc size of the PV system
CFA = Conditioned floor area
N_{Dwell} = Number of dwelling units
A = Adjustment factor from Table 170.2-T
B = Dwelling adjustment factor from Table 170.2-T

The minimum Prescriptive electrical output for this project is:
kWpv = (7,216 x 0.613)/1,000 + (8 x 1.36) = 15.3 kWdc

The proposed system has 15.6 kWdc output, so it complies prescriptively as designed.

11.9.7.2 Mid-Rise Multifamily Case Study

The Mid-Rise Multifamily Case Study covers a new five-story multifamily building in Sacramento, California (Climate Zone 12). This is a sample project created for training purposes, and it includes 112,044 ft² of conditioned floor area with 88 dwelling units, shared residential corridors, laundry rooms, fitness center and lounge, plus ground floor retail. The case study tables in this chapter compare the proposed building solar electricity and battery storage to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Table 11-78: Mid-Rise Multifamily Case Study Compared to Mandatory and Prescriptive Renewable Energy Requirements (Climate Zone 12)

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Mid-Rise Multifamily Building	New five-story mid-rise multifamily building, 88 dwelling units, common use areas, ground floor retail, Sacramento, CA	Section 110.10	Sections 170.2(g), 170.2 (h) and 140.10, Joint Appendices JA11 and JA12 New multifamily building ≥ four stories, Climate Zone (CZ) 12	Case study Mandatory and Prescriptive compliance rated for each feature below as "Yes" (complies), "No" (does not comply) or "N/A" (not applicable). If "No", see compliance options provided.
Dwelling Unit Conditioned Floor Area	78,384 ft²	N/A	170.2(g) and (h)	
Common Use Area Conditioned Floor Area	17,487 ft²	N/A	170.2(g) and (h)	
Retail Conditioned Floor Area	16,173 ft²	N/A	140.10	
Total Conditioned Floor Area	112,044 ft²	N/A		
Total Percent Multifamily in Mixed Occupancy Building	(78,384 + 17,487)/ 112,044 = 85.6%	N/A	Per 170.2(g) and 140.10(a), since multifamily is ≥ 80% of total CFA, the multifamily Prescriptive PV requirements apply to the whole building.	

Table 11-79: Photovoltaics (PV) and Battery Storage

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
PV System Electrical Output (kWdc)	123.2 kWdc	N/A	kWpvdc calculated per Equation 170.2-D: 247.6 kWdc kWpvdc calculated as SARA x 14 W/ft²: 194.8 kWdc Required kWpvdc is	Mandatory: N/A Prescriptive: No Compliance Options: 1. Redesign the PV panel installation to fit a total of 455 panels at 320 watts each.

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
			the smaller of these two calculations: ≥ 194.8 kWpvdc	2. Keep the same layout, but use 378 watt PV panels 3. Performance Approach
PV Solar Access Roof Areas (SARA)	10,395 ft² SARA to be verified using a certified solar assessment tool	N/A	Solar access to be verified using a certified solar assessment tool per Reference Appendix Section JA11.4	Mandatory: N/A Prescriptive: Yes
PV Panel Tilt	< 2:12 pitch	N/A	JA11 Any PV with < 2:12 pitch is defined as low-sloped	Mandatory: N/A Prescriptive: Yes
PV Panel Orientation	Installed on flat roof	Section 110.10	PV with < 2:12 pitch do not have orientation restrictions	Mandatory: Yes Prescriptive: Yes
Battery Storage Rated Single Charge-Discharge Cycle AC to AC (round trip) Efficiency	80%	N/A	≥ 80% per Reference Appendix Section JA12.2.2.1(b)	Mandatory: N/A Prescriptive: Yes
Battery Storage Rated Energy Capacity	225 kWh	N/A	Minimum kWhbatt calculated per Equation 170.2-E: (194.8 kWdc x 1.03 Wh/W)/√0.80 = 224.3 kWh	Mandatory: N/A Prescriptive: Yes
Battery Storage Rated Power Capacity	51 kWdc	N/A	Minimum kWbatt calculated per Equation 170.2-F: 194.8 kWdc x 0.26 = 50.6 kWdc	Mandatory: N/A Prescriptive: Yes
Verifications:	Contractor to verify solar access	N/A	Solar access verified using certified solar assessment tool	Mandatory: N/A Prescriptive: Yes

Source: California Energy Commission

Figure 81: Mid-Rise Multifamily Case Study: Photovoltaics (PV) on Flat Roof (viewed from South)

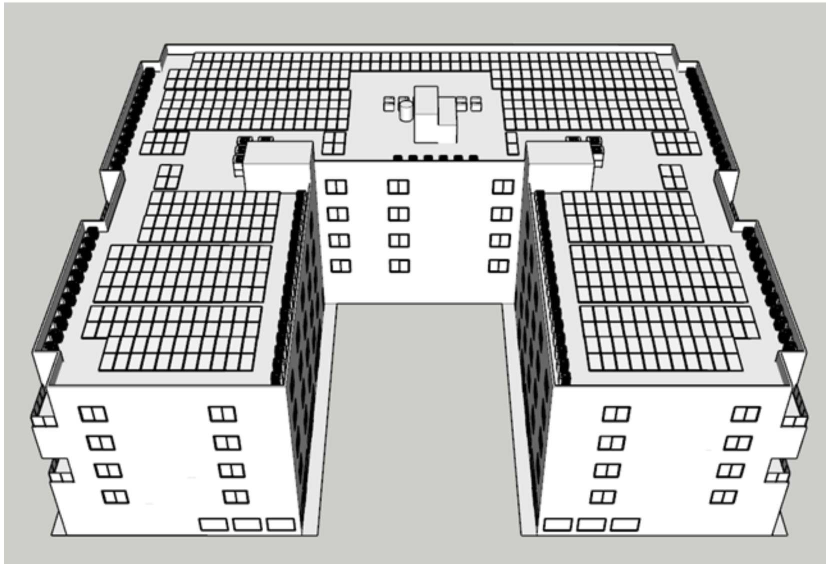


Figure 82: Mid-Rise Multifamily Case Study: 1st Floor Battery Storage Room

One important element of solar design is to make sure that the photovoltaic (PV) modules are installed in locations that have enough sunlight. The Energy Code requires solar access to be verified using a certified solar assessment tool per Reference Appendix Section JA11.4. The Solar Access Roof Area or SARA is the area of available roof surfaces for a building project that have at least 70 percent solar access and that are also structural able to support solar panels. SARA does not include the following:

- Occupied roofs per California Building Code Section 503.1.4:

  The deck roofs at the third and fifth floor balconies of this project are considered occupied roofs excluded from the SARA.

- sRoof space needed to comply with other building codes as confirmed by the Energy Commission Executive Director:

  Roof areas needed to meet California Fire Code (Title 24, Part 9) roof access and egress pathway requirements and roof areas needed around HVAC equipment to meet California Mechanical Code (Title 24, Part 4) requirements are both excluded from the potential SARA for this case study.

The Energy Code has two ways to calculate the prescriptive minimum kWdc of PV to be installed for multifamily buildings of more than three habitable stories. One way is to calculate it using Equation 170.2-D which is based on the total building floor area:

EQUATION 170.2-D PHOTOVOLTAIC DIRECT CURRENT SIZE

kWPVdc = (CFA x A)/1000

WHERE:

kWPVdc = Size of the PV system in kW

CFA = Conditioned floor area in square feet

A = PV capacity factor specified in Table 170.2-U for the building type

For this case study, this strategy results in:

kWpvdc calculated per Equation 170.2-D:
$(112,044\ ft^2 \times 2.21\ W/ft^2)/1,000 =$
247.6 kWdc

Based on the size and wattage of available PV panels, 247.6 kWdc will not fit on the proposed roof. The other way to calculate the Prescriptive PV requirement is to determine the available SARA square footage and multiply it by 14 watts per square foot. Using this method with a SARA of 10,395 ft^2 gives the following results:

kWpvdc calculated as SARA x 14 W/ft^2:
$(10,395\ ft^2 \times 14\ W/ft^2)/1000 =$
145.5 kWdc

The Prescriptive minimum required kWpvdc is the smaller of these two calculations or 145.5 kWpvdc. The design team did not achieve 145.5 kWpvdc in the available SARA. Their PV design only fit 385 PV panels at 320 watts each or 123.2 kWpvdc, so the PV system is out of compliance with the Prescriptive method as designed.

The design team has several Energy Code options to consider. One would be to see they can find a way to fit 455 – 320 watt PV panels in the available SARA. Another would be to keep the same layout with 385 PV panels, but to use a higher performing panel design with at least 378 watts output per panel. If the design team or the client objects to those options, they could work with an energy analyst to model the building overall using the Performance Approach to evaluate possible energy tradeoffs to achieve compliance.

11.10 Electric Ready Requirements

This section describes the mandatory requirements for electric readiness in multifamily buildings. The electric ready requirements apply to gas equipment used for dwelling unit space heating, water heating, and cooking as well as dwelling unit and common area clothes dryers. Electric ready requirements minimize future retrofit costs when electric appliances replace gas appliances. California has aggressive decarbonization goals: 100% carbon-free electricity by 2045 (Senate Bill 100) and reducing greenhouse gas emissions from buildings 40% below 1990 levels by 2030 (Assembly Bill 3232). To achieve these decarbonization goals, existing buildings will need to be retrofitted to use 100% carbon-free electricity.

11.10.1 What's New in 2022 Energy Code

Electric-readiness is a new mandatory requirement for dwelling unit gas space heating, water heating, cooking, and laundry for the 2022 Energy Code. Common use areas are exempt from the electric-ready requirement, with the exception of common use area clothes dryers.

11.10.2 Mandatory Requirements

§160.4, §160.9

Electric readiness requires the following for the applicable gas appliances listed in 11.12.

Installation of branch circuits within three ft. of existing gas appliances with no obstructions. These circuits are dedicated to future electric replacement equipment and cannot be used for other appliances. Other electrical components must be installed in accordance with the *California Electrical Code.*

1. Table 11-80 below describes the different circuit requirements for each gas end-use.
2. Dedicated space for double breakers in the main service panel that will serve the future in-unit space heating, electric cooktop and in-unit clothes dryers. The code does not require the installation of breakers at time of construction.

Dedicated space in the panel next to the location of the water heater breaker to accommodate converting it to 240V in the future, per §160.4. The dedicated space in the panels must be identified as "Future 240V Use." The code does not require the installation of breakers at time of construction.

Table 11-80 summarizes the electrical capacity, panel, and other equipment requirements for electric-readiness for each natural gas appliance installed in a new multifamily building. There are no electric ready requirements for additions or alterations. There are no performance or prescriptive electric ready requirements for multifamily buildings.

Table 11-80: Compliance Requirements for Electric Readiness

Gas or Propane Equipment Installed	Electrical Capacity requirements for new circuit (amps, volts)	Other Equipment Requirements
Furnace (dwelling unit only) §160.9(a)	240V, 30 amp	
Gas tankless or storage water heater (dwelling unit only) §160.4(a)	125V, 20 amp	A Category III or IV or Type B Vent with straight pipe from space where water heater is installed to outside termination Condensate drain no more than 2 inches higher than the base of installed water heater to allow for natural drainage with pump assistance
Gas or propane range (dwelling unit only) §160.9(b)	240V, 50 amp	
Dwelling unit gas clothes dryer §160.9(c)1	240V, 30 amp	
Common use area gas clothes dryer §160.9(c)2	24 amps at 208/240V per dryer or 2.6 kVA for each 10,000 btu/hr of rated gas input or electrical power required to provide equivalent function. This is usually determined by the electrical engineer on the project.	Conductor or raceway from the main electrical panel to within 3 ft. of the future electric equipment. Both ends of conductor labelled "Future 240V Use" Conductors, raceways and intervening electrical equipment must be sized to meet the future electrical load from the service voltage to the utility distribution system connection

Source: California Energy Commission

Receptacles are not required for the dwelling unit space heating, laundry, and cooking circuits. However, the unused circuits must have a blank cover identified as "240V ready." Receptacles are required for dwelling unit water heating, and must be connected to the panel with a 120/240V, 3-conductor 10AWG copper wire with both ends of the unused conductor labeled as *spare* and be electrically isolated.

Example 11-53

Question

Can I receive any compliance credit for making gas appliances electric-ready that are not required by code?

Answer

Because there are not any prescriptive or performance requirements for electric-readiness, you will not receive compliance credit for making a gas appliance electric-ready where not required by code. However, by doing so, you will minimize future retrofit costs. The project engineer should be able to recommend equivalent equipment and electrical requirements to ensure conduit and wires are sized appropriately, along with identifying additional physical space and panel capacity needs to accommodate the future heat pump technology.

Example 11-54

Question

There I am designing an apartment building with natural gas for in-unit water heating, clothes drying, and cooking. How much more electrical capacity can I expect from replacing my existing gas appliances with electrical appliances in the future on a subpanel for a 780 square foot apartment unit?

Answer

The example below demonstrates an estimated additional electrical capacity of 18,264 watts that a designer might account for when sizing panels for electrification of existing gas equipment in the future. The electric appliances that contributed to the additional capacity are shown in bold.

Figure 11-83: Electrical Load for All-Electric Dwelling Unit

Dwelling Unit Panel Calculation			
Electricity only	780	ft2	
	Volts	**Nameplate Amps**	**Total Watts**
General lighting & receptacle (sq.ft x 3 watts/sq.ft)	120	24	2,925
2 small appliance branch circuits	120	25	3,000
Clothes washer	120	10	1,200
Refrigerator	120	7	1,050
Bath fans	120	1	120
Range hood	120	5	600
Dishwasher	120	13	1,500
Waste disposal	120	5	600
Microwave	120	13	1,560
Range	**208**	**40**	**8,320**
Clothes dryer	**208**	**23**	**4,784**
Water heater	**208**	**24**	**5,000**
Total Watts			*30,659*
Total kVA			***31***
Diversity Factors (per California Electrical Code)			
First 10,000 watts at 100%			*10,000*
Remaining 20,659 Watts at 40%			*8,264*
Total Watts			*18,264*
Total kVA			***18***
Heat Pump	208	15	3,120
Heating element	120	2	240
Total A/C Watts at 100%			*3,360*
Total kVA			***3***
Total KVA Calculated (with diversity factors)			**21**
Total Amps for Panel @208V to provide 21 kVA			**101**

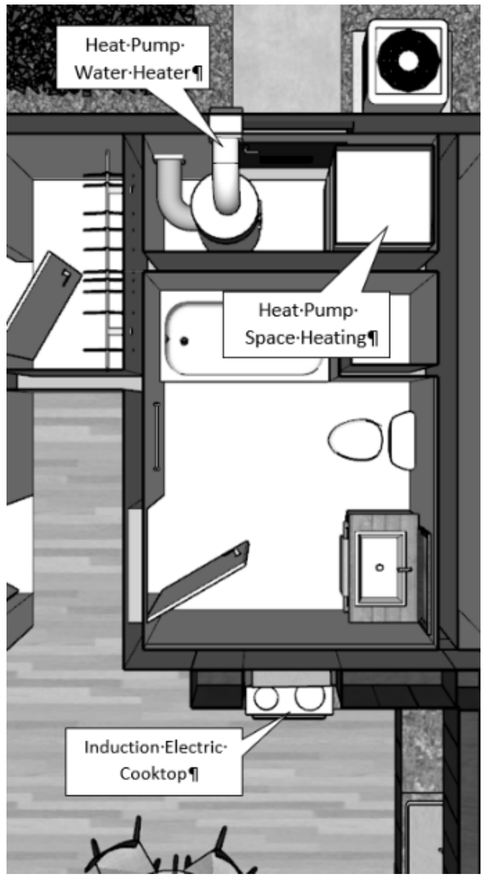
This example only considers the additional load requirements for an individual dwelling unit. To determine the additional load on the main service panel to accommodate whole building electrification, the additional capacity requirements for all dwelling units along with the applicable electric-ready requirements in common use area gas end uses will need to be considered in accordance with the California electrical code.

11.10.3 Code in Practice

11.10.3.1 Garden Style Multifamily Case Study

The Garden Style Multifamily Case Study considers a new two-story garden style multifamily building in Burbank, California (Climate Zone (CZ) 9). This is a sample project created for training purposes, and it consists of 7,216 ft² of conditioned floor area with eight dwelling units and no common use areas. The case study table in this chapter compare the proposed building electric readiness to Mandatory and Prescriptive Energy Code requirements and evaluate possible compliance options.

Figure 84: Garden Style Multifamily Case Study: Approved Electric Appliances Installed



The electric ready requirements are all mandatory requirements for new multifamily dwelling units that have gas or propane space or water heating, stoves, or clothes dryers. There are no other prescriptive electric ready requirements. This case study meets those requirements by actually installing electric heat pump space and water heating and an induction electric cooktop. The case study residences do not have clothes dryers, so that requirement does not apply.

Table 11-81: Garden Style Multifamily Case Study Compared to Mandatory and Prescriptive Electric Ready Requirements (Climate Zone 9)

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
New Multifamily Building	New two-story garden style multifamily building, eight dwelling units, no common use areas, Burbank, CA	Sections 160.9, 160.4(a): Systems and equipment using gas or propane to serve individual dwelling units must prepare for future electric replacements as highlighted below. See Energy Code for full details.	N/A	Case study Mandatory and Prescriptive compliance rated for each feature below as "Yes" (complies), "No" (does not comply) or "N/A" (not applicable). If "No", see compliance options provided.
Heat Pump Space Heating Ready	Not required, heat pump space heating being installed	Section 160.9(a): - Dedicated 240 volt branch circuit wiring installed, blank cover labeled "240V ready" - Reserve space in main electrical service panel for double pole circuit breaker for future heat pump labeled "For Future 240V Use"	N/A	Mandatory: Yes Prescriptive: N/A
Heat Pump Water Heater Ready	Not required, heat pump water heater being installed	Section 160.4(a)1: - Dedicated 125 volt, 20 amp electrical receptacle connected to electrical panel with 120/240 volt branch circuit - Unused conductor labeled "spare" and electrically isolated - Reserve space in panel for single pole circuit breaker next to branch circuit and label "Future 240V Use"	N/A	Mandatory: Yes Prescriptive: N/A
Electric Cooktop Ready	Not required, induction electric cooktop being installed	Section 160.9(b): Similar to 160.9(a) for heat pump space heating	N/A	Mandatory: Yes Prescriptive: N/A
Electric Clothes Dryer Ready	Not required, no dwelling unit clothes dryer being installed	Section 160.9(c)1: Similar to 160.9(a) for heat pump space heating	N/A	Mandatory: Yes Prescriptive: N/A
Verifications:	N/A	N/A	N/A	N/A

Source: California Energy Commission

11.10.3.2 Mid-Rise Multifamily Case Study

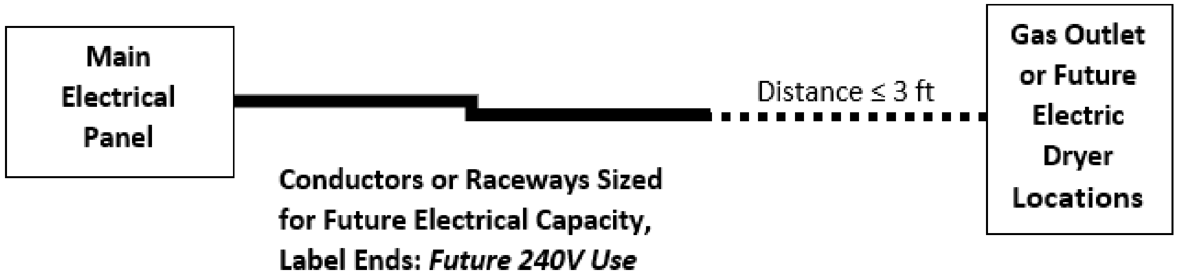
The Mid-Rise Multifamily Case Study covers a new five-story multifamily building in Sacramento, California (Climate Zone (CZ) 12). This is a sample project created for training purposes, and it includes 112,044 ft² of conditioned floor area with 88 dwelling units, shared residential corridors, laundry rooms, fitness center and lounge, plus ground floor retail. The case study table in this chapter compares the proposed building electric readiness to Mandatory and Prescriptive Energy Code requirements and evaluates possible compliance options.

Table 11-82: Proposed Building Electric Readiness to Mandatory and Prescriptive Energy Code Requirements

	CASE STUDY	MANDATORY	PRESCRIPTIVE	COMPLIANCE
Electric Cooktop Ready	Not required, induction electric cooktop being installed	Section 160.9(b): Similar to 160.9(a) for heat pump space heating	N/A	Mandatory: Yes Prescriptive: N/A
Electric Clothes Dryer Ready	Central laundry rooms with gas dryer(s) on 2nd through 5th floors: Electric ready requirements for common use clothes dryers will apply	Section 160.9(c)2A: - Conductors or raceways from main electrical panel to 3 feet or less from each gas outlet or location of future electric dryers. Label both ends "Future 240V Use." Size to meet future electrical loads per i, ii or iii below: i. 24 amps at 208/240V per dryer. ii. 2.6 kVA per 10 kBtuh rated gas input or gas pipe capacity; or iii. Electrical power calculated and documented by responsible person as equivalent to gas capacity.	N/A	Mandatory: Yes Prescriptive: N/A
Verifications:	N/A	N/A	N/A	N/A

Source: California Energy Commission

Figure 85: Electric Clothes Dryer Ready Diagram



The electric ready requirements are all mandatory requirements for new multifamily dwelling units that are served by gas or propane space or water heating or stoves, or by individual or common use clothes dryers. There are no other Prescriptive electric ready requirements. This case study meets the electric ready space heating, water heating and cooktop requirements by actually installing electric heat pump space and water heating and induction electric cooktops.

The case study residences share common laundry rooms with gas clothes dryers, so those areas must meet the electric ready requirements for common use clothes dryers. The basic requirement is to install electrical conductors or raceways that go from the main electrical panel to no more than three feet from each gas outlet or the proposed location of future electric clothes dryers. Generally, conductors may be different types of electrical wiring and raceways are supports or enclosures for electrical wires. The conductors or raceways must be sized according to Energy Code section 160.9(c)2A to meet the future electrical capacity needed for replacement electric dryers. Both ends of the conductors or raceways must be labeled "Future 240V Use."

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12 Performance Approach

Overview

This chapter summarizes the building performance approach to be used for compliance. It includes a discussion of the alternative calculation methods, the procedures involved in determining the energy budget of the Standard Design and the energy use of the Proposed Design Building, and how to plan check performance compliance documentation. The basic procedure is to show that the Time Dependent Valuation (TDV) and source energy use of the proposed design are less than or equal to the TDV and source energy budget of the standard design. The standard design is a building with the same geometry as the proposed design, but the envelope, lighting and mechanical features are defined by the mandatory and prescriptive requirements of the Building Energy Efficiency Standards (Energy Code). The standard design features are defined in detail in the Nonresidential and Multifamily Alternative Calculation Method (ACM) Reference Manual.

The performance method is the most detailed and flexible compliance path. The energy performance of a proposed building can be calculated according to actual building geometry and site placement. Credit for certain energy features, such as a high efficiency mechanical system, cannot be taken in the prescriptive approach, but can be evaluated with an approved compliance software program utilizing the performance approach

Performance Method Description

The ACM Approval Manual describes the application and approval process for submitted compliance software. The ACM Approval Manual is adopted as part of the Energy Standards rulemaking process. The Nonresidential and Multifamily ACM (NRMFACM) Reference Manual is approved by the California Energy Commission (Energy Commission) and includes explanations of the instructions that all compliance software programs must use to model the energy performance of the Proposed Design Building and the Standard Design Building. The reference manual also includes an explanation of the reference method and certification tests used by the Energy Commission to approve compliance software tools. Since the NRMFACM Reference Manual is approved by the Energy Commission (just like the residential and nonresidential compliance manuals), it can be updated from time to time to allow for corrections and enhancements during the 2022 Energy Standards cycle.

Performance Concepts

The Warren-Alquist Act requires “performance standards” that establish an energy budget for the building in terms of energy consumption per square foot of floor space. This requires a complex calculation of the estimated energy consumption of the building and the calculation is only suited for a computer. The Energy Commission has developed a public domain computer program to do these calculations known as California Building Energy Code Compliance (CBECC). For compliance purposes, The Warren-Alquist Act also authorizes the use of privately developed computer programs as alternatives to the public domain computer program. The public domain computer program and the Energy Commission approved privately developed programs are officially called alternative calculation methods. It is easiest to refer to these programs as "compliance software," which will be the term used throughout this manual.

Minimum Capabilities

Compliance software must simulate or model the thermal behavior of buildings including envelope surfaces, lighting, space conditioning, and service water heating systems. The calculations take into account:

- Conductive, convective, and radiative heat gain and loss through walls, roof/ceilings, doors, floors, windows, and skylights.
- Solar radiant heat gain from windows and skylights.
- Heat storage effects of different types of thermal mass.
- Building operating schedules for people, lighting, equipment, and ventilation.
- Space conditioning system operation including equipment part load performance.
- Some covered process mechanical equipment can be modeled (kitchens, laboratories, parking garages, etc.). Details of which covered process equipment is modellable in CBECC are in the NRMFACM Reference Manual.

California Energy Commission Approval

Alternative Calculation Methods (Compliance Software)

Compliance software must be approved by the Energy Commission. Approval involves the demonstration of minimum modeling capabilities, required input and output, and adequate user documentation. The compliance software must be able to:

1. Automatically calculate the energy budget of the standard design.
2. Calculate the energy budget of the proposed design in accordance with specific fixed and restricted inputs.
3. Print the appropriate standardized compliance documents with the required information and format when a proposed building complies. Other reports that do not resemble compliance documents may be printed for buildings that do not comply.

Input and Output Requirements

Input and output requirements and modeling capabilities are tested by using the compliance software to calculate the energy use of certain prototype buildings under specific conditions. These results are compared with the results from the reference public domain compliance software, CBECC, which uses EnergyPlus as the simulation engine. This is explained in detail in the NRMFACM Reference Manual.

Building Performance Metrics

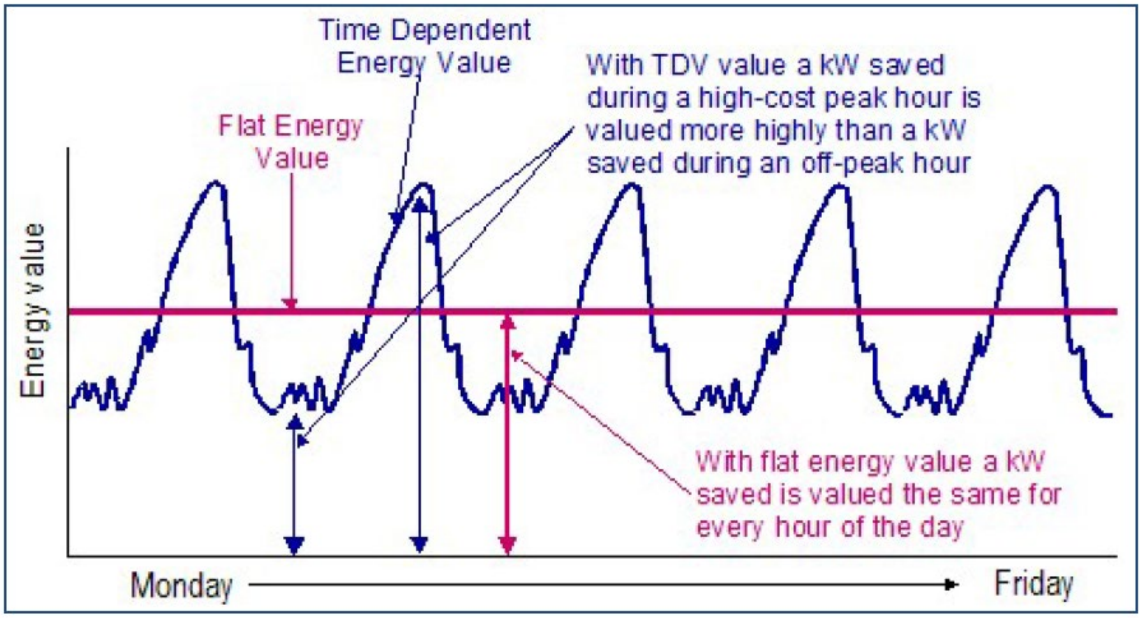
Beginning with the 2005 Energy Standards, the metric or "currency" for assessing building performance has been time dependent valued (TDV) energy. TDV energy replaced annual source energy that had been the compliance metric since the Energy Commission first adopted the Energy Standards in 1978. Starting with the 2022 code cycle, compliance will be based on both TDV and hourly source energy (HSE). For a proposed building to comply, both its TDV and HSE energy use must be less than or equal to the standard design energy budgets. More details on how proposed design energy use and the standard design energy budgets are calculated and how compliance is determined can be found in the NRMFACM Reference Manual and the CBECC or third-party compliance software user's manuals.

Time Dependent Valuation (TDV)

As the name implies, the TDV metric values energy differently depending on the day of the year and hour of the day that a specific type of energy is used. This means that electricity saved on a hot summer afternoon will be worth more in the compliance process than the same amount of electricity saved earlier in the morning when temperatures are mild, HVAC loads are lower, and electricity grid demand for energy is lower. The value assigned to energy savings through TDV more closely reflects the long-term costs for electricity, natural gas, and propane and provides compliance credit for measures that results in load shifting from peak periods to off-peak periods.

Reference Appendix JA3 provides more information on TDV energy. A comparison of TDV energy and flat energy cost are shown below in Figure 12-1.

Figure 12-1: Time Dependent vs. Flat Energy Value



Source: California Energy Commission

Hourly Source Energy (HSE)

HSE is an energy metric for electricity, natural gas, and propane. Put simply, HSE represents the amount of long-term depletable energy resources used to meet the energy demand of the building in each hour. HSE values are very similar to the long-term hourly utility greenhouse gas (GHG) emissions and a strong metric for encouraging building decarbonization.

Because HSE is based on depletable energy use, when renewable resources are used to generate energy, the source energy value decreases for that hour. In hours where renewable resources are scarce, source energy values increase. This means that energy savings during the night, when solar generation is low, is more valuable in HSE than savings during the morning when solar generation is greater.

Professional Judgment

Certain modeling techniques and compliance assumptions applied to the proposed design are fixed or restricted. That is, there is little or no freedom to choose input values for energy compliance modeling purposes. However, there are other aspects of energy modeling where some professional judgment may be necessary. In those instances, the compliance software user must decide whether a given input is appropriate and will be matched by the actual installation.

Enforcement agencies have discretion to question a particular input if the permit applicant cannot substantiate the value with supporting documentation, cannot demonstrate that appropriate judgment has been applied or cannot demonstrate that the actual installation matches the input.

Simplified modeling approaches can be used if the predicted energy use of the proposed building is not affected or if the proposed energy use increases, reducing the compliance margin when compared to a more explicit and detailed modeling assumption. That is, simplification must reflect the same or higher energy use than a more detailed model and reflect the same or lower compliance margin when comparing the standard and proposed TDV energy and HSE.

Any unusual modeling approach, assumption, or input value should be documented with published data and, when applicable, should conform to standard engineering practice.

Example 12--1

Question

Three different sized windows in the same wall of a new one-story office building are designed without exterior shading, and they have the exact same NFRC-rated U-factors and SHGC values. Is it acceptable professional judgment to simplify the computer model by adding the areas of the three windows together and inputting them as a single fenestration area?

Answer

Yes. For a simplified, two-dimensional, geometry model, the compliance software will produce approximately the same energy results whether the windows are modeled individually or together as one area because the orientation, fenestration U-factors and SHGC values of the windows are identical.

However, if overhangs and side-fins are modeled, the correct geometry of fixed shades must be modeled for each window.

For detailed, three-dimensional, geometry models, the location of windows on walls affects the daylighting energy calculation and this affect must be considered before making the simplification in the example.

For reference, to help determine if you're using a detailed or simplified approach, a wall in a simplified model will be entered as an area, orientation (i.e., North, South, East, West), height, and width. In a detailed model a wall is entered as a series of points (i.e., x, y, z coordinates) to place the wall in three-dimensional space relative to other surfaces in the building.

Analysis Procedure

§140.1

This section is a summary of the analysis procedures used to demonstrate building compliance when using approved compliance software programs. Software users and those checking for enforcement should consult the most current version of the compliance software user's manual and/or on-line help and associated compliance supplements for specific instructions on the operation of the compliance software. Although there are numerous requirements for each software input, the data entered into each software version may be organized differently from one vendor to the next. As a result, it is not possible in this summary to present all variables in their correct order or hierarchy for any one software version. The aim is to identify the procedures used to calculate the standard and proposed design TDV energy and HSE budgets.

General Procedure

Any compliance software version approved by the Energy Commission may be used to comply with the Energy Standards. The following steps are a general outline of the process:

1. All detailed data for the building components must be collected including areas and performance properties (i.e., U-factor, SHGC, R-Value, and other thermal properties) for fenestration, walls, doors, roofs, ceilings, floors, and other construction assemblies; and specifications for HVAC and other mechanical equipment, lighting systems, and water heating systems based on the building design plans, drawings, and/or specifications.

2. Although most compliance software requires the same basic data, some information requirements, and the way it is organized in the software may vary according to the software used. Refer to the compliance supplement that comes with each version of compliance software for details.

3. Be sure that the correct climate information has been selected for the building site location (see Reference Appendix JA2). Compliance software also adjusts outside heating and cooling design temperatures for local conditions using ASHRAE design data that is also located in Reference Appendix JA2.

4. Prepare an input file that describes the other thermal aspects of the proposed design according to the rules described in the software's compliance supplement.

5. Input values and assumptions must correctly correspond to the proposed design and conform to the required mandatory measures.

6. Run the compliance software to automatically generate the energy budgets of the proposed and standard design buildings.

Computer Input Files

When creating any computer input file, use the space provided for the project title information to describe concisely and uniquely the building that is being modeled. User-designated names should be clear and internally consistent with other buildings being analyzed in the same project. Title names and explanatory comments should assist individuals involved in both the compliance and enforcement process.

Basic Data Entry

Elements Used in Compliance Software

The following elements are examples of the information used by compliance software programs to calculate the standard design energy budget and proposed design building energy use. All information entered into the proposed building model, like those shown below, must be consistent with the plans and specifications submitted in the building permit application:

- **Opaque Walls**: Each opaque exterior wall construction assembly, wall area, orientation, and tilt. Heat capacities, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior walls, must be included. Interior demising wall area and characteristics must also be input.
- **Doors**: All doors must be included.
- **Opaque Roofs/Ceilings**: Each opaque exterior roof/ceiling construction assembly, roof/ceiling area, solar reflectance, thermal emittance, orientation, and tilt. Heat capacity, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior roof/ceilings, must be included.
- **Raised Floors and Slab Floors**: Each floor construction assembly, including floor area.
- **Fenestrations in Walls and Shading**: Each vertical glass area, orientation, tilt, U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT). Shading from permanently affixed shading devices, such as window overhangs and fins should be included in the model. Shading inputs consist of device depth, distance, and extension relative to the glass.
- **Horizontal (Skylight) Fenestration**: Each horizontal or skylight glass area, orientation, tilt, U-factor, SHGC, and VT.
- **Ventilation Air**: Ventilation (introduction of outside air) values in cubic feet per minute (cfm).
- **Fan Power**: Fan power must be included. Fan power should be based on shaft brake horsepower at the equipment's rated condition (modeled horsepower must be substantiated by information contained in the construction documents).
- **Cooling and Heating Efficiency**: The efficiency of the equipment included in the proposed design at AHRI conditions.

- **HVAC System Type**: The basic type of the cooling and heating system (multiple zones or single zone) and the heating system fuel type (fossil fuel or electric). Note that some projects may have different system types serving separate zones.
- **Sensible and Total Cooling System Capacity**: Sensible and total output capacity of the cooling system at AHRI conditions.
- **Heating System Capacity**: The output capacity of the heating system.
- **Indoor Lighting:** Lighting loads and modeling non-mandatory controls for credit.
- **Water Heating:** The water heating capacity, volume, and efficiency (including any solar thermal contribution).
- **Photovoltaic (PV) and Battery Storage:** Required inputs include PV system direct current (DC) size in kW, description of PV system (i.e., standard or premium modules, fixed or tracking array, microinverters or DC power optimizers, solar access percentage), battery system capacity in kWh, and battery system description (i.e., basic or advanced control, and charge/discharge efficiencies and rate)
- **Other System Values**: All other space conditioning system components, process loads, or any other mechanical system that impacts the building energy performance must be included in the input file.

Refer to the compliance software user's manual for information on all required modeling inputs and more detailed information on how each input is used by the software.

Calculating Building Energy Use

The TDV and HSE proposed design energy use and standard design energy budgets are separated into compliance totals, which are the basis for building compliance with the performance method, and total building energy use, which adds receptacle, process and other nonregulated energy usage.

The compliance total energy can be summarized into three main components:

1. The space conditioning energy use.
2. The indoor lighting energy use.
3. The service water heating energy use.

Non-regulated energy; process, receptacle, other lighting, and process motors; is treated as compliance neutral. The standard design will always match the proposed energy usage for these categories.

The proposed building energy use is defined by §140.1(b) (nonresidential) and §170.1(b) (multifamily) and includes the envelope, space conditioning and ventilation, indoor lighting, and water heating systems assigned to the building. The key component of calculating the TDV energy and HSE use of the proposed building is that if a feature of the building is not included in the building permit application, the energy use of that feature is equal to that of the standard design energy budget defined in §140.1(a) (nonresidential) or §170.1(a) (multifamily). That means that if a permit is submitted for a building shell (envelope only), and the performance approach is used to demonstrate compliance, trade-offs cannot be made between the envelope and the mechanical or lighting system.

The standard design budget is defined by replacing all of the energy features of the proposed building with the prescriptive requirements in §140.3 (nonresidential) or §170.2 (multifamily) of the Energy Code. Details of the standard design features are documented in the NRMFACM Reference Manual.

Space Conditioning Energy Budget

The space conditioning energy budget is automatically determined from the software's user inputs and the corresponding elements of the proposed design. This budget is automatically re-calculated with each compliance run.

Lighting Energy Budget

The indoor lighting energy budget consists of the lighting power used by a building based on one of the following criteria:

- When no lighting plans or specifications are submitted for permit and the occupancy of the space is not known, the standard lighting power density is 0.40 W/ft².
- When no lighting plans or specifications are submitted for permit and the occupancy of the space is known, the standard lighting power is equal to the corresponding watt per ft² value derived in the Area Category Method of §140.6(c)2 (nonresidential) or §170.2(e)3C (multifamily).
- When lighting plans and specifications are submitted for permit, the standard lighting power is equal to the corresponding total allowed lighting power (in watts) that was used in calculating the proposed lighting level which can be based on either the Area Category Method or the Tailored Method in §140.6(c)2 or 3 (nonresidential) or §170.2(e)3C or D (multifamily). A complete set of lighting plans and prescriptive documents are required to use the Tailored Lighting Method in the performance approach. When this method is used to justify an increase in the allowed lighting watts, a lower lighting load in the proposed design cannot be modeled for credit. The standard design building uses the lesser of allowed watts or actual lighting power to be installed in the building. The proposed design building uses the actual lighting power to be installed as detailed on

the lighting plans. This value must be equal to or less than the allowed watts.

For all occupancies except hotel guest rooms and multifamily dwelling units, the proposed lighting power is input into the software. For hotel guest rooms or multifamily dwelling units, the compliance software will automatically set the proposed lighting power and the standard design lighting power at the same value as specified in the NRMFACM Reference Manual.

Water Heating Energy Budget

The service and domestic water heating energy budgets consist of the water heating energy used by a building assuming the water heating systems meet both the mandatory and prescriptive requirements for water heating.

The service and domestic water heating standard designs are documented in the NRMFACM Reference Manual.

Application Scenarios

The performance approach may be used for whole building permit applications; or for permit applications that involve combinations of building envelope, indoor lighting, domestic hot water (DHW)/service hot water (SHW), and/or mechanical systems. The performance method may be used to demonstrate compliance with the envelope or mechanical system alone but can't be used to show lighting or DHW compliance alone. A permit stage is when less than a whole building is being considered (e.g., the building envelope would be constructed in one permit phase, the mechanical system in another).

Whole Building Compliance

Whole buildings are projects involving buildings where the applicant is applying for permits and submitting plans and specifications for all the major components of the building (envelope, mechanical, indoor lighting, and DHW/SHW). This also could be a first-time tenant improvement that involves envelope, mechanical and lighting compliance, where plans and specifications for the entire building are being submitted for permit.

When a whole building is modeled using the performance approach, trade-offs can be made between the envelope, space conditioning, DHW/SHW, and indoor lighting systems that are included in the permit application.

Compliance by Permit Stage

Compliance with only one or more building permit stages can be done using the performance approach except that indoor lighting cannot be done alone. A permit stage is a portion of a whole building permit: either envelope, mechanical, or lighting. This means that trade-offs in energy use are limited to only those features, or a single feature in the case of envelope or mechanical, included in the building permit application. DHW and SHW are not considered a permit stage, but these systems may be optionally included (or not included) in the scope of a performance compliance permit.

When building features are outside the scope of the performance compliance permit, those components will automatically be modeled the same in both the standard design and proposed design by the compliance software. By doing this, the software makes these features compliance neutral; meaning no credit or penalty is given for those features. The NRMFACM Reference Manual and the compliance software user's manual describe these rules and standard design values in detail.

There are two basic scenarios where a building feature will be outside the scope of a performance compliance permit:

1. Modeling future construction features that are not included in the permit application (e.g., future mechanical and lighting systems that are not part of the scope for an envelope only permit).
2. Modeling existing construction that has already complied with the Energy Code (e.g., envelope components, that were permitted in an earlier stage of construction, but are not part of the scope for a mechanical and lighting only compliance run).

Modeling Future Construction by Permit Stage

When a building feature is not included in the performance calculation and permit, that feature will be defaulted automatically by the compliance software. The defaulting rules vary for envelope, mechanical, and indoor lighting. The NRMFACM Reference Manual and software user's manual contain additional information on these defaulting rules.

Envelope features can't be defaulted for permitting at a future stage. Usually, the envelope is the first permit for a building and a fully defined envelope is a requirement for calculating the building's energy budget.

If mechanical is excluded from the scope of the performance permit, in the case of envelope and/or lighting compliance, the default space conditioning system features are determined as described in the NRMFACM Reference Manual for the mechanical system. In general, the compliance software will create a default, minimum efficiency HVAC system, to neutralize mechanical system compliance.

If lighting is excluded from the scope of the performance permit, the default lighting system features depend on whether the occupancy of the space is known. If the space occupancy is known, the allowed lighting power is determined using the Area Category Method for each zone that the occupancy is known. If the space occupancy is not known, 0.40 W/ft² is assumed for both the proposed and standard design buildings.

If DHW and/or SHW are excluded from the scope of the performance permit, the default DHW/SHW system is determined as described in the NRMFACM Reference Manual. In general, a default, minimum efficient DHW and/or SHW system will be automatically created and used in the proposed building model.

Modeling Existing Construction by Permit Stage

When existing indoor lighting or an existing mechanical system is not included in the permit application, the compliance software may use default values for certain inputs. The NRMFACM Reference Manual contains additional information on the default values.

For existing envelopes, there are no automatic defaults. The user must enter details for the existing envelope, i.e., conditioned floor area, glazing, walls, floors/soffits, roofs/ceilings, and display perimeters. Based on the proposed envelope, the software will create a matching standard design envelope. By doing this all existing envelope features are compliance neutral, no credit or penalty.

To model an existing mechanical system, a user can either input the existing space conditioning system; including the type of equipment, actual sizes, and efficiencies; or specify that the existing system is unknown. When the existing system is entered, the compliance software uses the proposed building's space conditioning features to create a matching standard design mechanical system. This means that all existing mechanical systems in the proposed model are compliance neutral, no credit or penalty. When the system is unknown, the software will automatically create a minimally efficient HVAC system in the proposed design.

The default service water heating system is determined as described in the NRMFACM Reference Manual and will only be listed as "Existing".

Existing lighting system features are based on the known occupancy of the building and whether information on the existing system is known. The lighting power entered for the proposed model is determined based on either the Area Category lighting power allowances for the proposed design occupancies, or if the existing design lighting power is known the actual design data should be entered instead. The compliance software then creates a standard design matching the proposed design so that compliance is neutral, no credit or penalty, for the existing lighting system.

Additions Performance Compliance

An addition that consists of both new conditioned floor area and added volume will either need to comply as an addition alone or as an existing plus addition plus alteration. For the addition alone path, the same requirements for a newly constructed building will apply to the addition. All systems serving the addition will require compliance to be demonstrated; and either the prescriptive or performance approach can be used for each stage of the construction of the addition. Existing plus addition plus alteration requires modeling of the existing, altered, and new components, but gives the opportunity for compliance tradeoffs between the new and altered components in the addition and existing building.

When existing space conditioning or water heating is extended from the existing building to serve the addition, the existing components of these systems should be modeled as existing and the new components of these systems must be modeled as new (e.g., new ducts extended to the addition) so that the software can determine the correct standard design based on section 141.0(a) (Nonresidential) or 180.1 (multifamily).

Addition Only

Additions that show compliance with the performance approach independent of the existing building must meet the requirements for newly constructed buildings. §141.0(a) (Nonresidential) and §180.1 (Multifamily) state that the envelope and indoor lighting of the addition, and any newly installed space conditioning, electrical power distribution system, or water heating system must meet mandatory measures and the applicable energy budget:

- If the permit is done in stages, the rules for each permit stage apply to the addition's performance run.
- If the whole addition (envelope, lighting and mechanical) is included in the permit application, the rules for whole buildings apply.

Existing Plus Addition Plus Alteration

Additions may also show compliance by either:

7. Demonstrating that efficiency improvements to the envelope component of the existing building, as well as certain indoor lighting and mechanical improvements, offset addition performance that would otherwise not meet the energy budgets for the addition alone (see §141.0(a)2Bii (Nonresidential) or 180.1(b)2 (Multifamily)).
8. Showing that the existing building combined with the addition meet the requirements of §141.0(b) (Nonresidential) or §180.2 (Multifamily) for newly constructed buildings.

For additions, the most flexible compliance method is to consider the entire existing building along with the addition (Existing + Addition + Alteration)[1]. The combination

[1]This method may also be used whenever an alteration is made to existing buildings, whether or not there is an addition to the building at the same time.

of additions and alterations to the existing building may be shown to comply by demonstrating that the proposed design energy use is equal to or less than the standard design energy budget based on the alterations meeting the requirements of §141.0(b)3 (Nonresidential) and §180.2(c) (Multifamily) and additions meeting the requirements of §141.0(a)2 (Nonresidential) or 180.1(b) (Multifamily). Additionally, §141.0(a)2 (Nonresidential) and §180.1(b) (Multifamily) state that the envelope and indoor lighting in the conditioned space of the addition, and any newly installed space conditioning, electrical power distribution system or service water heating system, must meet the mandatory measures.

This approach allows the applicant to improve the energy efficiency of the existing building so that the entire building meets the energy budget that would apply if the existing building were unchanged, and the addition complied on its own. Changes to features in the existing building are considered alterations.

For a full description of when and how altered components in the existing building are counted as a credit or penalty in the performance calculation, as well as basic energy modeling rules for alterations, see the Alterations Performance Compliance section 12.5.4 below.

Example 12--2

Question

3,000 ft² of conditioned space is being added to an existing office building. 25% of the lighting fixtures in the existing office space are being replaced with more efficient fixtures. Can credit be taken for the improved lights in the existing building to comply through the existing-plus-addition performance approach?

Answer

Since 10% or more of the lighting fixtures are replaced, all prescriptive lighting alteration requirements must be met. Credit can only be taken for lighting efficiency improvements resulting in a lower lighting power than is required to meet §140.6 (Nonresidential) and §170.2(e) (Multifamily).

Alterations Performance Compliance

Using the performance approach for an alteration is similar to demonstrating compliance for an addition.

Alterations of the Permitted Space

Altered spaces can show compliance with the performance approach independent of the remainder of the existing building but must still meet the requirements for the altered components of the building as specified in §141.0(b)2 (Nonresidential) and §180.2(b) (Multifamily). These require that envelope and lighting alterations, as well as any new or replacement space conditioning or service water heating system serving the alteration, meet the mandatory measures. The permitted space alone may comply with the energy budget determined using approved compliance software.

If the permit is done in stages, the rules for each permit stage apply to the alteration performance run.

Alterations in Existing Buildings without an Addition

Alterations may also show compliance by demonstrating that the energy use of the proposed design -- including all energy efficiency improvements to the existing building -- is equal to or less than the standard design energy budget which is based on the alterations meeting the requirements of §141.0(b)2 (Nonresidential) and §180.2(b) (Multifamily) and Table 141.0-E (Nonresidential) of the Energy Code. Note that §141.0(b)1 (Nonresidential) and §180.2(a)(Multifamily) also require that envelope, lighting, space conditioning and service water heating system alterations meet the applicable mandatory measures.

This approach allows the applicant to improve the energy efficiency of the existing building so that it meets the energy budget that would apply to the entire building if the existing building other than the portion being altered was unchanged. Changes to features in the existing building are considered alterations.

An energy penalty is assigned to any altered component that does not meet or exceed the requirements of §141.0(b)2 (Nonresidential) or §180.2(b) (Multifamily). A credit is assigned to an alteration (improvement) that exceeds the requirements in §141(b)2 (Nonresidential) or §180.2(b) (Multifamily) as summarized in Table 141.0-E (Nonresidential) of the Energy Code and further detailed in the NRMFACM Reference Manual. For Nonresidential, the compliance software sets the standard design for the altered component as listed in Table 141.0-E of the Energy Code and for multifamily the software sets the standard design based on the requirements of §180.2(b).

This compliance approach includes the entire building which means the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all conditioned and unconditioned space within the structure. The inclusion of the characteristics of unconditioned spaces have an effect on the overall performance budget of the building due to the loads of the unconditioned spaces adjacent to the conditioned spaces which can be beneficial or detrimental to the overall compliance margin.

When using this compliance approach, it is important to take into account all changes in the features of the building that are:

- **EXISTING** (that remain unchanged).
- **ALTERED** (improved or replaced).
- **NEW** (all new).

Note that surfaces which are being completely removed from the existing building – roofs/ceilings, exterior walls and floors, and all glazing removed with those removed surfaces – are not modeled.

To show compliance with this approach you need to follow the instructions in the compliance software user's manual. Documentation of the existing building's glazing areas is required to be submitted with the permit application if this method is used for replacement fenestration credit.

Example 12-3

Question

Alterations to an existing office building in Climate Zone 12 includes replacing all single clear metal frame operable windows with new NFRC-rated windows (U-factor =0.45, SHGC=0.31.) What standard design values will the compliance software use for the replacement fenestration area?

Answer

The standard design will use the values in Table 141.0-A (U=0.47, SHGC=0.31 and VT=0.32) of the Energy Standards regardless of whether the replacement windows' values exceed those Table 141.0-A values of the Energy Standards.

Alterations in Existing Buildings With an Addition

See Existing Plus Addition Plus Alteration section in this chapter.

Alternate Performance Compliance Approach

Any addition, alteration or repair may demonstrate compliance by meeting the requirements applicable to newly constructed buildings for the entire building. Using this method, the entire building could be shown to comply in permit stages or as a whole building. The rules for new buildings permit stage compliance (Section 12.5) and whole building compliance (Section 12.5.1) would apply.

Documentation of the existing building's features is required to be submitted with the permit application if this method is used.

Enforcement and Compliance

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the documents and procedures for documenting compliance with the performance requirements. The NRMFACM Reference Manual has specific and detailed output/reporting requirements for all approved compliance software.

Compliance software output is required to specify the run initiation time, a unique run code, and the total number of pages of documents printed for each proposed building run on each page whenever a building complies with the Energy Code. The plan checker is strongly encouraged to verify these output features for a performance compliance submittal to ensure that the submittal is a consistent set of compliance documentation. The NRMFACM Reference Manual forbids compliance software from printing valid compliance documents for a proposed building design that does not comply. The plan checker should pay special attention to the PRF-01 document and the Exceptional Conditions List on that document. Every item on the Exceptional Conditions List deserves special attention and may require additional documentation, such as manufacturer's cut sheets or special features on the plans and in the building specifications.

The compliance software requirements will automatically produce and reiterate the proper set of documents that correspond to the proposed building submitted for a permit. However, the plan checker should verify the type of compliance and the required documents. Whenever an existing building or existing building components are involved in the compliance calculation, the plan checker should look for the term EXISTING that identifies EXISTING building components that remain unchanged. Similarly, if the compliance document indicates a component is ALTERED these changes should be verified. In permit applications where some building components are unknown, the unknown components cannot be entered by the user and cannot be reported on output documents. The PRF-01 document will show all the pertinent information required for a complete submittal.

The compliance documents associated with the performance approach are generated automatically and the entire printout is called the PRF-01.

Unless minimal efficiency and default capacities are used in the performance analysis, design drawings or specifications must be provided to document the differences in the capacities and efficiencies of the proposed equipment.

Other documentation supporting each non-standard or non-default value used in the performance approach and indicated in the Exceptional Conditions list on the PRF-01 document must also be included.

Performance Inspection

Performance approach inspection is identical to other inspections required by the Energy Standards. For information on inspection of envelope, mechanical and lighting systems, refer to Chapter 2, Compliance and Enforcement.

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13 Building Commissioning Guide

Commissioning is included in the design and construction process of newly constructed nonresidential buildings to verify that the building's energy systems and components meet the owner's or owner representative's project requirements.

Commissioning under Part 6 is required for nonresidential buildings of 10,000 square feet and larger, excluding healthcare facilities (which instead follow a procedure specified in Chapter 7 of the California Administrative Code, Title 24, Part 1). Commissioning is also required for nonresidential portions of mixed-use buildings when the total space of these portions is 10,000 square feet or larger.

Newly constructed buildings with less than 10,000 square feet of nonresidential area are only required to perform a design review, though they may elect to perform a more complete commissioning process. Design review is discussed in Section 12.4.
Part 6 does not require retrocommissioning of existing buildings; neither commissioning nor design review are required for building additions or alterations. That said, this guide may still be useful for projects engaging in retrocommissioning.

13.1 Overview

The following key terms and acronyms refer to important concepts in commissioning:

Acronyms

- BOD - Basis of Design
- Cx - Commissioning
- FPT - Functional Performance Test
- HVAC - Heating, Ventilating, and Air Conditioning
- O&M - Operations and Maintenance
- OPR - Owner's Project Requirements

Glossary

- **Acceptance Criteria -** The conditions that must be met for systems or equipment to meet defined outcomes.
- **Commissioning (Cx) -** Building commissioning as required in this code is a quality assurance process that begins during design and continues to occupancy. Commissioning verifies that the new building and its systems are planned, designed, installed, tested, operated and maintained as the owner intended, and the building staff are prepared to operate and maintain its systems and equipment.

- **Commissioning Coordinator -** The person who plans, schedules and coordinates the commissioning team to implement the commissioning process. This can be either a third-party commissioning provider or an experienced member of the design team or owner's staff.
- **Commissioning Team -** The people designated to provide insight and carry out tasks necessary for commissioning. Team members may include the commissioning coordinator, owner, owner's representative, building staff, design professionals, contractors, manufacturer's representatives, and testing specialists.
- **Complex Mechanical Systems** - Mechanical Systems that includes
  1. fan systems each serving multiple thermostatically controlled zones; or
  2. built-up air handler systems (non-unitary or non-packaged HVAC equipment); or
  3. hydronic or steam heating systems; or
  4. hydronic cooling systems. Complex mechanical systems are NOT the following:
     a. unitary or packaged equipment listed in Tables 110.2-A, 110.2-B, 110.2-C, and or 110.2-E that each serves one zone, or
     b. two-pipe, heating only systems serving one or more zones.

  NOTE: Mechanical Systems that are not considered, "Complex" are the following:
     a. unitary or packaged equipment listed in Tales 110.2-A, 110.2-B, 110.2-C or 110.2-E that each serves one zone, or
     b. two-pipe, heating only systems serving one or more zones and is not a Complex Mechanical System
- **Design Reviewer** - The person who reviews the design documents to ensure the design will likely meet the OPR.
- **Independent Third-Party Commissioning Professional (Authority/Agent/Provider/Lead) -** An entity contracted by the owner who is not responsible or affiliated with any other member of the design and construction team. This professional leads, plans, schedules, and coordinates the commissioning team and activities.
- **Operation and Maintenance (O&M) Manuals -** Documents that provide information necessary for operating and maintaining installed equipment and systems.
- **Owner -** The individual or entity holding title to the property on which the building is constructed.
- **Owner Representative -** An individual or entity assigned by the owner to act and sign on the owner's behalf.

- **Sequence of Operation -** A written description of the intended performance and operation of each control element and feature of the equipment and systems.
- **Scope of the Commissioning Requirements -** All building systems and components covered by §110.0, §120.0, §130.0, and §140.0 must be included in the scope of the commissioning requirements, excluding covered processes.

13.1.1 Selecting Trained Personnel for Commissioning

It is important to designate one person to lead and manage the commissioning activities. This person is referred to as the commissioning coordinator in this manual. Other terms commonly used for this person are commissioning authority, agent, provider, or lead.

The commissioning coordinator must manage the commissioning process, including the development and implementation of the commissioning tasks and associated documents. Trained personnel must execute the tasks and may include members of the owner's staff, contractors, design team, and independent commissioning professionals.

The commissioning coordinator may be an independent third-party commissioning professional, a project design team member (e.g. engineer or architect), an owner's engineer, contractor, or specialty sub-contractor. Evaluation of the designated commissioning coordinator and trained personnel includes reviewing:

- Technical knowledge.
- Experience.
- Potential conflict of interest.
- Professional certifications and training.
- Communication and organizational skills.
- Reference and sample work products.

13.2 Owner's Project Requirements (OPR)

§120.8(b)

The Owner's Project Requirements document (OPR) establishes the owner's goals, requirements and expectations for everything related to energy consumption and operation. The energy-related expectations and requirements of the building must be documented before the design phase of the project. This document includes:

1. Energy efficiency goals.
2. Ventilation requirements.
3. Project program, including facility functions and hours of operation, and need for after-hours operation.
4. Equipment and systems expectations.

13.2.1 Intent

The OPR documents the functional requirements of the project and expectations of the building use and operation as it relates to systems being commissioned. The OPR describes the physical and functional building characteristics desired by the owner and establishes performance and acceptance criteria. The OPR is most effective when developed during pre-design and used to develop the BOD during the design process. The detail and complexity of the OPR will vary according to building use, type, and systems.

13.2.2 Compliance

The owner or owner's representative shows compliance by developing or approving the OPR before the design phase. An OPR template is available in the NRCC-CXR-E document. The OPR should include:

A. ***Energy Efficiency Goals*** **-** Establish energy efficiency goals, which may include:

1. Overall energy efficiency.
2. Lighting system efficiency.
3. HVAC equipment efficiency & characteristics.
4. Any other measures affecting energy efficiency desired by the owner
    a. Building orientation and siting
    b. Daylighting
    c. Facade, envelope, and fenestration
    d. Roof
    e. Natural ventilation
    f. Onsite renewable power generation and zero net energy use
    g. Landscaping and shading

B. ***Ventilation Requirements*** - Describe indoor ventilation requirements including intended use and schedule for each program space.

C. ***Project Program, including facility functions and hours of operation, and need for after-hours operation* -** Describe primary purpose, program, and use of proposed project, such as:

1. Building size, number of stories, construction type, occupancy type, and number.
2. Building program areas including intended use and anticipated occupancy schedules.
3. Future expandability and flexibility of spaces.
4. Quality and/or durability of materials and building lifespan desired.
5. Budget or operational constraints.
6. Applicable codes.

D. ***Equipment and Systems Expectations -*** For each system commissioned describe the:

1. Level of quality, reliability, equipment type, automation, flexibility, maintenance, and complexity desired.
2. Specific efficiency targets, desired technologies, or preferred manufacturers for building systems.
3. Degree of system integration, automation, and functionality for controls (i.e. load shedding, demand response, and energy management).

E. ***Building Envelope Performance Expectations –*** For each assembly that contains a special feature describe the:

1. Assembly type, such as, floors, foundations, walls, ceilings, and roofs.
2. Characteristics that merit special attention.

F. ***Enforcement -*** The building official confirms compliance at *plan review* by either:

1. Receipt of a copy of the OPR (optional).
2. Receipt of a completed NRCC-CXR-E indicating the OPR was reviewed at the design review kickoff.

13.3 Basis of Design (BOD)

§120.8(c)

A written explanation of how the design of the building systems meets the OPR must be completed at the design phase of the building project, and updated as necessary during the design and construction phases. The BOD covers following systems and components:

1. HVAC systems and controls.

2. Indoor lighting system and controls.
3. Water heating systems and controls.
4. Any building envelope component considered in the OPR.

13.3.1 Intent

The BOD describes the building systems to be commissioned and outlines design assumptions not indicated in the design documents. The design team develops the BOD to describe how the building systems design meets the OPR, and why the systems were selected. The BOD is most effective when it is developed early and updated during the design process.

13.3.2 Compliance Method

Compliance requires the completion of the BOD, which should include:

A. HVAC Systems and Controls

1. Provide a description of system –type, location, controls, efficiency features, outdoor air ventilation strategy, indoor air quality features, environmental benefits, and other special features.
2. Describe reasons for system selection – why chosen system is better than alternatives, considering issues such as comfort, performance, efficiency, reliability, flexibility, simplicity, cost, owner preference, site constraints, climate, maintenance, and acoustics.
3. Provide design criteria including:
   a. Load calculation method/software.
   b. Load calculation assumptions.
   c. Summer outdoor design conditions, °F drybulb and °F wetbulb.
   d. Winter outdoor design conditions, °F drybulb and °F wetbulb.
   e. Indoor design conditions, °F drybulb cooling, %RH cooling; °F drybulb heating, % RH heating.
   f. Applicable codes, guidelines, regulations and other references used.
4. Sequence of Operations – operating schedules and setpoints (may refer to plans or specifications).

B. Describe how the system meets the OPR **Indoor Lighting System and Controls**

1. Provide a description of system – type of fixtures, lamps, ballasts, and controls.
2. Describe reason for system selection – why chosen system is better than alternatives, considering issues such as visual comfort, performance,

efficiency, reliability, cost, flexibility, owner preference, color rendering, integration with daylighting, and ease of control.

3. Provide design criteria for each type of space including:
   a. Applicable codes, guidelines, regulations and other references used.
   b. Illumination design targets (footcandles) and lighting calculation assumptions.
4. Provide lighting power design targets for each type of space
   a. Lighting power allowance and lighting power design target (watts/ft²).
5. Describe how system meets the OPR.

C. Water Heating Systems and Controls

1. Provide a description of system – system type, control type, location, efficiency features, environmental benefits, and other special features.
2. Describe reason for system selection – why chosen system is better than alternatives, considering issues such as performance, efficiency, reliability, space constraints, cost, utility company incentives, owner preference, and ease of maintenance
3. Water heating load calculations.
4. Describe how system meets the OPR.

D. Building Envelope Components

1. Provide a description of system – type, energy savings, and payback period.
2. Describe reason for system selection – why chosen system is better than alternatives, considering issues such as performance, efficiency, reliability, flexibility, simplicity, expandability, cost, payback period, utility company incentives, and owner preference.
3. Describe how system meets the OPR.

13.3.3 Enforcement

The building official confirms compliance at plan review by either:

1. Receipt of a copy of the BOD document (optional).
2. Receipt of a completed NRCC-CXR-E indicating the BOD was reviewed at the design review kickoff attesting that the BOD has been completed and meets the requirements of the OPR.

13.4 Design Phase Review

§120.8(d)

1. Design reviewer requirements are based on the project size and complexity of the mechanical systems, as follows:
   a. For newly constructed buildings less than 10,000 square feet, design phase review may be completed by the engineer or architect of record.
   b. For newly constructed buildings between 10,000 and 50,000 square feet, it may be completed by a qualified in-house engineer or architect with no other project involvement or a third party engineer, architect, or contractor.
   c. For newly constructed buildings larger than 50,000 square feet or buildings with complex mechanical systems, an independent review by a third-party engineer, architect, or contractor.
2. Design Review. During the schematic design phase of the building project, the owner or owner's representative, design team and design reviewer must meet to discuss the project scope, schedule and how the design reviewer will coordinate with the project team. The building owner or owner's representative must include the Design Review Checklist in the Certificate of Compliance (see §10-103).
3. Construction Documents Design Review. The design review forms list the items that must be checked by the design reviewer during the construction document review. The completed forms must be returned to the owner and design team for review and sign-off. The building owner or owner's representative must include the design review forms in the Certificate of Compliance (see §10-103).

13.4.1 Intent

The intent of design phase review is to improve compliance with the Energy Code, encourage adoption of best practices in design, and lead to designs that are constructible and maintainable.

13.4.2 Compliance Method

Compliance requires completion of the Design Review Kickoff and Construction Document checklists by the design reviewer. Requirements for the design reviewer are provided in §120.8(d)1. The following steps are required to complete this requirement:

A. Design Review Kickoff - Initial Schematic Review

1. A meeting is held between the project owner (or owner's representative), design team representatives (including mechanical and electrical design engineers, project architect), commissioning coordinator, and design reviewer.

2. Meeting topics to be discussed include:
   a. Project coordination, including design reviewer involvement.
   b. Project scheduling, including design review.
   c. Project scope.
   d. OPR and BOD.
   e. Design Elements and assumptions.
   f. HVAC system selection.
   g. Construction documents design review checklists to be completed.
   h. Energy Efficiency Measures.
   i. Complete and Sign Certificate of Compliance – Cx Design Review Kickoff NRCC-CXR-E.

B. Construction Document Review

1. The design team provides the design reviewer with a set of plans and specifications late in design as agreed upon in design review kickoff, typically around 90 percent construction document completion.
2. The design reviewer provides a review of the commissioning documents - NRCC-CXR-E:
3. Completed form is submitted to the design team and project owner for consideration.
4. The designer provides a response on the Construction Document compliance documents. The design reviewer is not required to provide a second review of the construction documents for compliance purposes.
5. Certification of Completion - The design reviewer, design engineer, and owner/owner's representative sign the Certificate of Compliance – Cx Design Review Signature Page, NRCC-CXR-05-E, indicating that the construction documents design review has been completed.

The commissioning coordinator who meets the requirements may also complete the construction documents design review.

13.4.3 Enforcement

Compliance is shown by completion of the NRCC-CXR-E.

13.5 Commissioning Measures

§120.8(e)

This section includes commissioning measures or requirements in the construction documents (plans and specifications) for newly constructed nonresidential buildings.

Commissioning measures or requirements should be clear, detailed, and complete. These requirements should include:

- The list of systems and assemblies commissioned.
- Testing scope.
- Roles and responsibilities of contractors.
- Requirements for meetings.
- Management of issues.
- The commissioning schedule.
- O&M manual development and training.
- Checklist and functional test compliance document development, execution and documentation.
- Roles of non-contractor parties (for information only).

13.5.1 Intent

Include commissioning measures or requirements in the construction documents (plans and specifications). Commissioning measures or requirements should be clear, detailed and complete to clarify the commissioning process.

13.5.2 Existing Law or Regulation

The Energy Code requires specific functional test compliance documents (Certificate of Acceptance) to be included in the construction documents. These functional test compliance documents are a part of the commissioning requirements.

13.5.3 Compliance

Compliance is achieved by including commissioning requirements in the project plans and specifications. The commissioning specifications should include:

A. Primary (and optionally all) commissioning requirements are included in the general specification division (typically Division 1) and clear cross references of all commissioning requirements to and from the general division are included to ensure all subcontractors are held to them.

B. A list of the systems and assemblies covered by the commissioning requirements.

C. Roles and responsibilities of all parties including:

   1. General contractor, subcontractors, vendors, and construction manager.
   2. Commissioning coordinator.

3. Owner and facility staff.
4. Architect and design engineers.
5. Non-contractor parties (for information only to provide the contractor with context for their work).
6. The individual who writes checklists, tests, reviews and approves functional test compliance documents, directs and executes tests, records test results, and approves completed tests. These roles may vary by system or assembly.

D. Meeting requirements.

E. Commissioning schedule management procedures.

F. Issues and non-compliance management procedures.

G. Requirements for execution and documentation of installation, checkout, and start up, including control point-to-point checks and calibrations.

H. Specific testing requirements by system, including:

1. Monitoring and trending.
2. Opposite season or deferred testing requirements, functions and modes to be tested.
3. Conditions of test.
4. Acceptance criteria and any allowed sampling.
5. Details of the format and rigor of the functional test compliance documents required to document test.
6. Example compliance documents (recommended).

I. Submittal review and approval process.

J. Content, authority, and approval process of the commissioning plan.

K. Commissioning documents and reporting requirements.

L. Facility staff training requirements and verification procedures.

M. O&M manual review and approval procedures.

N. System’s manual development and approval requirements and procedures.

O. Definitions section.

13.5.4 Enforcement

The building official can confirm compliance at plan review by a receipt of a copy of the commissioning specifications.

13.6 Commissioning Plan

§120.8(f)

Prior to permit issuance, a commissioning plan must be completed to document how the project will be commissioned and must be started during the design phase of the building project. The commissioning plan must include:

A. General project information.

B. Commissioning goals.

C. Systems to be commissioned.

D. Plans to test systems and components:

1. An explanation of the original design intent.
2. Equipment and systems to be tested, including the extent of tests.
3. Functions to be tested.
4. Conditions under which the test is performed.
5. Criteria for acceptable performance.
6. Commissioning team information including roles.
7. Commissioning activities, schedules, and responsibilities. Plans for the completion of commissioning requirements listed in §120.8(g) through §120.8(i).

13.6.1 Intent

The commissioning (Cx) plan establishes the guidelines for the project and commissioning team's level of effort. It identifies the required Cx activities to ensure that the OPR and the BOD are met. The Cx plan also includes a commissioning schedule from design to occupancy.

13.6.2 Existing Law or Regulation

Review local county, city, or jurisdiction ordinances for any applicable commissioning planning requirements.

13.6.3 Compliance

Compliance is shown by completing the Cx Plan. The following gives guidance for developing the Cx plan:

A. ***General project information*** **-** Provide project identifying information, including:

1. Project name, owner, and location.

2. Building type and area.
3. Project schedule.
4. Contact information of individual or company providing the commissioning services.

B. *Commissioning Goals –* Record the commissioning goals, including:

1. Code requirements.
2. OPR and BOD requirements.
3. Requirements for commissioning activities in plans and specifications.

C. *Systems to be commissioned* – See BOD

1. *An explanation of the original design intent* - Document the performance objectives and design intent for each system to be commissioned
   a. Refer to the OPR and BOD documents.
2. *Equipment and systems to be tested, including the extent of tests*
   a. Provide a list of equipment and systems to be tested.
   b. Describe the range and extent of tests to be performed for each system component, and interface between systems
3. *Functions to be tested* - Provide example functional test procedures to identify the level of testing detail required.
4. *Conditions under which the test* must *be performed* - Identify the conditions under which the major operational system functions are to be tested, including:
   a. Normal and part-load operations.
   b. Seasonal testing requirements.
   c. Restart of equipment and systems after power loss.
   d. System alarm confirmations.
5. *Measurable criteria for acceptable performance* - Include criteria for acceptable performance of each system to be tested.

D. *Commissioning Team Information* **-** Provide a contact list for all Commissioning team members, including:

1. Owner and/or owner's representative.
2. Architect and engineers.
3. Designated commissioning representative.
4. General contractor, sub-contractors, and construction manager.

E. *Commissioning process activities, schedules, and responsibilities*

1. Establish commissioning steps and activities to be accomplished by the Cx team throughout the design to occupancy.

2. Define the roles and responsibilities for each member of the Cx team for each phase of work.
3. List the required Cx deliverables, reports, compliance documents, and verifications expected at each stage of commissioning.
4. Include the confirmation process for the O&M manual, systems manual, and the facility operator and maintenance staff training.

13.6.4 Enforcement

The building official can confirm compliance at plan review by receipt of a copy of the Cx plan.

13.7 Functional Performance Testing

§120.8(g)

Functional performance tests must show the correct installation and operation of each component, system, and system-to-system interface in accordance with the acceptance test requirements. Functional performance testing reports must include information addressing each of the building components tested, the testing methods used, and any readings and adjustments made.

13.7.1 Intent

Functional performance tests ensure that all components, equipment, systems, and system-to-system interfaces were installed as specified, and operate according to the OPR, BOD, and plans and specifications.

The systems to be functionally tested and listed in the BOD:

1. HVAC systems and controls.
2. Indoor lighting system and controls.
3. Water heating system and controls.
4. Building envelope components.

13.7.2 Existing Law or Regulation

Acceptance testing requirements call for functional testing of some systems and equipment. Refer to Chapter 13, Acceptance Requirements, in this manual for further guidance.

Although functional performance testing for commissioning under §120.8 is related to acceptance testing, the systems to be functionally tested are based on systems described in the BOD. Not all of the systems described in the BOD will have acceptance testing requirements per the Energy Code. Some acceptance tests must be performed by a certified acceptance test technician, see Chapter 13 for more details.

13.7.3 Compliance

Compliance is shown by developing and implementing test procedures for each piece of commissioned equipment and interface between equipment and systems according to the building-specific Cx plan. The tests should verify the proper operation of all equipment features, each part of the sequence of operation, overrides, lockouts, safeties, alarms, occupied and unoccupied modes, loss of normal power, exercising a shutdown, startup, low load through full load (as much as possible) and back, staging and standby functions, scheduling, energy efficiency strategies, and loop tuning. Acceptance requirements, discussed in Chapter 13, are required and contribute toward compliance with §120.8(g), but do not cover all necessary testing.

A**cceptable test procedures include:**

1. Date and Party - Identification of the date of the test and the party conducting the test.
2. Signature Block - Signature of the designated commissioning lead and the equipment installing contractor attesting that the recorded test results are accurate.
3. Prerequisites - Any conditions or related equipment checkout or testing that needs to be completed before conducting this test.
4. Precautions - Identification of the risks involved to the test team members and the equipment and how to mitigate them.
5. Instruments - List of the instruments and tools needed to complete the test.
6. Reference - In each procedure, identify the source for what is being confirmed (e.g., sequence of operation ID, operating feature, specification requirement, etc.).
7. Test Instructions - Step-by-step instructions of how to complete the test, including functions to test and the conditions under which the tests should performed.
8. Acceptance Criteria - Measurable pass / fail criteria for each step of the test, as applicable.
9. Results - Expected system response and space to document the actual response, readings, results and adjustments.
10. Return to Normal **-** Instructions that all systems and equipment are to be returned to their as-found state at the conclusion of the tests.
11. Deficiencies - A list of deficiencies and how they were mitigated.

13.7.4 Enforcement

The building official confirms compliance during *field inspection* by either:

1. Receipt of a copy of the completed and signed Functional Performance Tests that indicate any deficiencies have been corrected (optional).
2. Review of acceptance certificates (NRCA's) attesting that the Functional Performance Tests have been completed and any deficiencies corrected. Although there are no field forms for commissioning requirements, authorities having jurisdiction can review issues logs or the certificates of acceptance to verify field testing was completed and issues resolved.

13.8 Documents and Training

§120.8(h), Documentation and Training.

A systems manual and systems operations training are required.

§120.8(h)1, Systems Manual.

The operation of the building and its systems must be included in the systems manual and delivered to the building owner or representative and facilities operator. The systems manual must include:

1. Site information, including facility description, history, and current requirements.
2. Site contact information.
3. Instructions for basic O&M, including general site operating procedures, basic troubleshooting, recommended maintenance requirements, and site events log.
4. Description of major systems.
5. Site equipment inventory and maintenance notes.

A copy of all special inspection required by the enforcing agency or the Energy Code.

13.8.1 Intent

The systems manual provides information needed to understand, operate, and maintain the equipment and systems. It informs those not involved in the design and construction of the building systems. This manual is in addition to the record construction drawings, documents, and the O&M Manuals supplied by the contractor. The systems manual is assembled during the construction phase and available during the contractors' training of the facility staff.

The systems operation training verifies that a training program is developed to provide training to the appropriate maintenance staff for each equipment type and/or system and this training program is documented in the commissioning report. The systems operations training program is specified in the project specifications for the major systems listed. The System Manual, O&M documentation, and record drawings are prepared and available to the maintenance staff prior to implementation of any training or the development of a written training program. The training program is to be administered by the commissioning coordinator or other responsible party when the appropriate maintenance staff is made available to receive training.

13.8.2 Compliance Method

Compliance is shown by providing the systems manual. The systems manual includes:

A. ***Site information, including facility description, history and current requirements***

1. Site Information
    a. Location of property - Address
    b. Site acreage
    c. Local utility information:
        i. Water service provider
        ii. Natural/LPG gas service provider
        iii. Electrical service provider
        iv. Telecommunications service provider
        v. Other service provider
2. Facility Description
    a. Use/function
    b. Square footage
    c. Occupancy Type
    d. Construction Type
    e. BOD
    f. Location of major systems & equipment
3. Project History
    a. Project requirements
        i. OPR
        ii. BOD
    b. Project undocumented events
    c. Record drawings and documents
    d. Final control drawings and schematics

   e. Final control sequences
   f. Construction documents - Location or delivery information:
      i. Mechanical & electrical drawings
      ii. Specifications
      iii. Submittals
      iv. Project change orders and information
4. Current requirements
   a. Building operating schedules
   b. Space temperature, humidity, & pressure, CO_2 setpoints
   c. Summer and winter setback schedules
   d. Chilled & hot water temperatures
   e. As-built control setpoints and parameters

B. *Site contact information*

1. Owner information
2. Emergency contacts
3. Design team: architect, mechanical engineer, electrical engineer, etc.
4. Prime contractor contact information
5. Subcontractor information
6. Equipment supplier contact information

C. *Basic operation* and *maintenance, including general site operating procedures, basic trouble shooting, recommended maintenance requirements site events log*

1. Basic operation
   a. Equipment operation instructions
   b. Interfaces and interlocks
   c. Initial maintenance provided by contactor
2. General site operating procedures
   a. Instructions for changes in major system operating schedules
   b. Instructions for changes in major system holiday and weekend schedules
3. Basic troubleshooting
   a. Cite any recommended troubleshooting procedures specific to the major systems and equipment installed in the building.
   b. Manual operation procedures
   c. Standby/backup operation procedures

    d. Bypass operation procedures
    e. Major system power fail resets and restarts
    f. Trend log listing

4. Recommended maintenance events log
    a. HVAC air filter replacement schedule & log
    b. Building control system sensor calibration schedule & log
5. Operation & Maintenance Manuals - Location or delivery information

D. ***Major Systems***

1. HVAC systems & controls
    a. Air conditioning equipment (chillers, cooling towers, pumps, heat exchanges, thermal energy storage tanks, etc.)
    b. Heating equipment (boilers, pumps, tanks, heat exchanges, etc.)
    c. Air distribution equipment (fans, terminal units, accessories, etc.)
    d. Ventilation equipment (Fans, accessories, and controls)
    e. Building automation system (workstation, servers, panels, variable frequency drives, local control devices, sensors, actuators, thermostats, etc.)
2. Indoor lighting systems & controls
    a. Lighting control panels
    b. Occupancy sensors
    c. Daylight harvesting systems
3. Renewable energy systems
    a. Photovoltaic panels & inverters
    b. Wind powered electrical generators & inverters
4. Landscape irrigation systems
    a. Water distribution diagrams
    b. Control system
5. Water reuse systems
    a. Reclaimed water system for indoor use
    b. Reclaimed water for irrigation use

E. ***Site equipment inventory and maintenance notes***

1. Spare parts inventory
2. Frequently required parts and supplies
3. Special equipment required to operate or maintain systems
4. Special tools required to operate or maintain systems

F. *A copy of all special inspection verifications required by the enforcing agency of this code*

G. *Other resources and documentation*

While not required, an issues log is a useful tool to keep track of the status of equipment repairs and it should be maintained by the facilities indefinitely. The log, in conjunction with an equipment inventory, can be used to track and manage issues with specific pieces of equipment or systems over time. An issues log is a formal and record of problems or concerns discovered within a facility and the recommended solution to those problems. This living document could be created by the Cx team and maintained throughout the course of the investigation and implementation phase of a Cx project. The issues log should list the following:

1. Issue number
2. Building name or number
3. Floor
4. Location or room number
5. Equipment tag
6. Observation method
7. Issues description
8. Recommended resolution
9. Resolution responsibility
10. Action taken
11. Date of action taken
12. Resolution status
13. Verified by
14. Verification date

13.8.3 Enforcement

The building official can confirm compliance during field inspection by a receipt of a copy of the systems manual.

13.9 Systems Operations Training

§120.8(h)2

The training of the maintenance staff for each equipment type or system must be documented in the commissioning report. Training materials must include:

1. System and equipment overview (i.e. what is the equipment, its function, and with what other systems or equipment does it interface).
2. Review and demonstrate operation, servicing, and preventive maintenance.
3. Review of the information in the systems manual.
4. Review of the record drawings on the systems and equipment.

13.9.1 Compliance

The written training program includes:

- Learning goals and objectives for each session.
- Training agenda, topics, and length of instruction for each session.
- Instructor information and qualifications.
- Location of training sessions (onsite, off-site, manufacturer's or vendor's facility).
- Attendance forms.
- Training materials.
- Description of how the training will be archived for future use that includes:

A. *Systems/equipment overview*

1. Review OPR and BOD related to the major systems and equipment
2. Describe system type and configuration
3. Explain operation of all major systems and equipment and how it works with other systems and equipment
4. Describe operation of critical devices, controls, and accessories
5. Review location of the major systems and equipment
6. Describe operation of control system for each system, location of critical control elements, and procedures to properly operate control system
7. Review recommendations for implementation to reduce energy and water use

B. *Review and demonstration of servicing/preventive maintenance*

1. Explain location or delivery contact of the Operation & Maintenance manuals
2. Review of all manufacturer's recommended maintenance activities to maintain warranty
3. Review and demonstrate frequent maintenance activities (air filter replacement, lubrication, fan belt inspection and/or replacement, condenser water treatment, etc.), and suggested schedule

4. Review and demonstrate typical service procedures and techniques (electrical current, pressure, flow readings, calibration procedures, point trending, power fail restart procedures, etc.)
5. Locate, observe, and identify major equipment, systems, accessories and controls
6. Review emergency shut-offs and procedures

C. *Review the Systems Manual*

1. Describe use of Systems Manual
2. Review elements of Systems Manual
3. Explain how to update and add revisions to Systems Manual

D. *Review record drawings on the systems/equipment*

1. Explain location or delivery contact of the record drawings
2. Review record drawings, revisions, and changes to original design drawings
3. Review equipment schedules and compare with actual installed systems

13.9.2 Enforcement

The building official can confirm compliance during field inspection by:

1. Receipt of a copy of the written training program and completed attendance forms.
2. Receipt of a copy of the training program provided to the owner or owner's representative.

13.10 Commissioning Report

§120.8(i)

A complete report of commissioning process activities undertaken through the design, construction and reporting recommendations for post-construction phases of the building project must be completed and provided to the owner or representative.

13.10.1 Intent

The commissioning report documents commissioning and test results. The report includes confirmation from the commissioning coordinator that commissioned systems meet the conditions of the OPR, BOD, and contracts.

13.10.2 Compliance Method

The commissioning report includes:

A. Executive summary of process and results of commissioning – including observations, conclusions, and any outstanding items.

B. History of any system deficiencies and how resolved
   1. Include outstanding deficiencies and plans for resolution
   2. Include plans for seasonal testing scheduled for a later date

C. System performance test results and evaluations

D. Summary of training completed and scheduled

E. Attach commissioning process documents
   1. Commissioning Plan
   2. OPR
   3. BOD
   4. Executed installation checklists
   5. Executed functional performance test compliance documents
   6. Recommendations for end-of-warranty review activities

13.10.3 Enforcement

The building official can confirm compliance during *field inspection* by receipt of a copy of the commissioning report.

Example 12-1

Question

I am constructing a 100,000 ft2 mixed occupancy building. 10 percent of the conditioned floor area is for commercial/retail use, and the remaining spaces are residential. Since the building is primarily residential, does it need to be commissioned?

Answer

Yes. Because the nonresidential portion of the building is 10,000 square feet or greater, it will need to be commissioned. However, the commissioning requirements of Section 120.8 only apply to the nonresidential portions of the building.

Example 12-2

Question

I am constructing a mixed occupancy building which has both residential and nonresidential spaces. The water heating system serves both the residential and nonresidential spaces of the building. Do I need to include the water heating system in the building commissioning?

Answer

Yes. Since the water heating system is serving both residential and nonresidential spaces, the water heating system must be included in commissioning.

Example 12-3

Question

Is commissioning required for nonresidential buildings which have less than 10,000 ft2 of conditioned space?

Answer

No, although the design review portion of commissioning is required.

Example 12-4

Question

Do the commissioning requirements apply to tenant improvements (first time buildouts) for multi-tenant buildings such as a strip mall?

Answer

Possibly, it depends on the local enforcement agency's policy. Commissioning may be completed for the entire building prior to tenant improvements, or for each individual tenant improvement. Check with your local enforcement agency for their commissioning policies for multi-tenant buildings.

Example 12-5

Question

Do the commissioning requirements apply to unconditioned nonresidential buildings?

Answer

No, the scope of the Energy Standards does not include commissioning (Section 120.8) for unconditioned nonresidential buildings in Section 100.0(e)2C.

Example 12-6

Question

Is third party design review required for buildings with complex systems that serve less than 10,000 square feet?

Answer

No, the licensed professional engineer who completes and signs the Design Review Kickoff Certificate(s) of Compliance, and the Construction Document Design Review Checklist Certificate(s) of Compliance does not need to be a third party (see Section 10-103(a)1).

Example 12-7

Question

Are covered processes required to be included in commissioning?

Answer

No, covered processes are excluded from the commissioning requirements (see Section 120.8). Covered processes can be included in the Basis of Design document (see Section 120.8(c)), however it is not required.

Example 12-8

Question

Can the person responsible for commissioning also perform acceptance testing?

Answer

It depends. A commissioning professional can perform acceptance testing provided that they have also gained certification as an Acceptance Test Technician (or ATT). A commissioning professional that is not an ATT cannot perform acceptance tests that are reserved to ATTs.

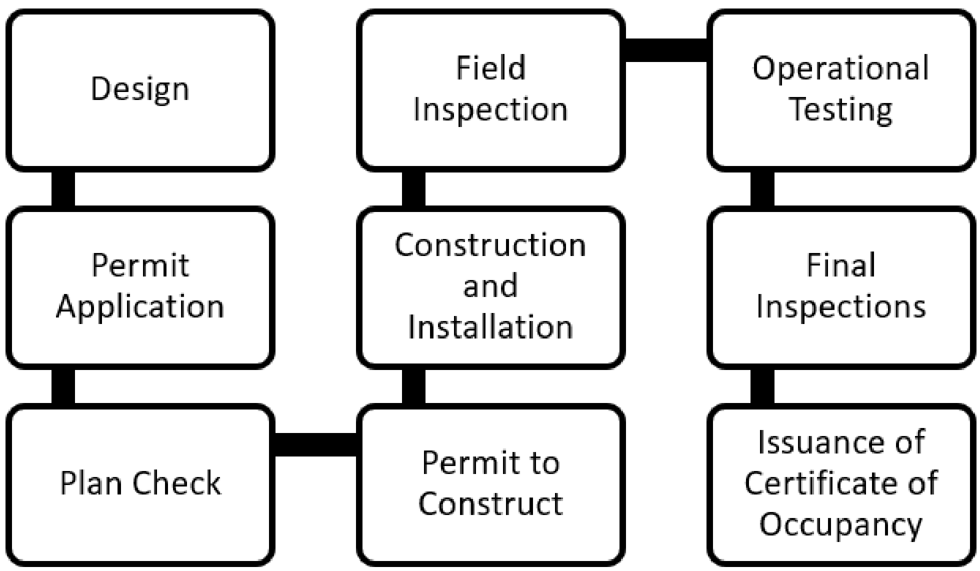
Table of Contents

14. Acceptance Test Requirements

14.1 Overview

Acceptance testing is performed during the Operational Testing phase of project permitting (shown in Figure 14.1-1) and prior to final inspections and the issuance of the Certificate of Occupancy. See Nonresidential and Multifamily Compliance Manual Chapter 2 for more information regarding the phase of project permitting.

Figure 14.1-1: Idealized International Code Council Permitting Process for Building Permit Applications



Source: California Energy Commission staff

However, it is advisable (although not required) to include professionals who are knowledgeable regarding the acceptance test procedures and requirements in the Design phase as well.

14.1.1 What Is Acceptance Testing

From simple thermostats and manual light switches to complex building automation systems, controls are integral to building health, safety, comfort, and energy efficiency.

Acceptance test requirements specify targeted inspections and functional performance tests that demonstrate that the building components, equipment, systems, and interfaces conform to the *2022 Building Energy Efficiency Standards* (or *Energy Code*, inclusive of Reference Nonresidential Appendix NA7), as specified on applicable construction documents.

This helps ensure that the building achieves the energy savings potential specified in its design and protects installing technicians by providing demonstrable proof that the system functioned as required by code when it was installed.

14.1.2 Roles and Responsibilities

Please see Nonresidential and Multifamily Compliance Manual Chapter 2 for a complete discussion concerning the roles and responsibilities of all parties

14.1.2.1 .Field Technician

The *field technician* is responsible for performing and documenting the results of the acceptance testing procedures on the certificate of acceptance documents. The field technician must sign the certificate of acceptance to certify that the information provided on the certificate of acceptance is true and correct. The field technician does not require a contractor’s, architect's or engineer's license but may require certification as an acceptance test technician (ATT).

While it is preferred that the same field technician that performed the installation also perform the acceptance test, it is not required. A separate technician (or contractor, engineer, architect, or even the responsible person) can perform the acceptance test and sign for the field technician.

14.1.2.2 Acceptance Test Technician

An ATT is a certification standard for technicians, contractors, engineers, architects, and commission agents that design, install, and commission (perform acceptance testing) for lighting controls and mechanical system in newly constructed or existing nonresidential buildings or spaces.

The certification is restricted to applicants with a minimum of three years of professional experience and expertise in either lighting or mechanical controls. Qualifying experience for certification is provided by verifiable employment as an electrical contractor, certified general electrician, licensed architect, professional engineer, controls installation and startup contractor, HVAC installer, mechanical contractor, Testing and Balancing certified technician, or certified commissioning professional with verifiable experience in lighting controls or HVAC installations. ATTs are provided classroom and laboratory training to perform acceptance testing. ATTs must pass classroom and laboratory testing to gain their certification. The ATT is required to work with the California Energy Commission (CEC) approved acceptance test technician certification provider (ATTCP) to track and verify quality assurance of their acceptance test performance.

- A certified lighting controls ATT is required to perform the lighting controls acceptance tests referenced by §130.4 and §160.5(e), and to sign the certificate(s) of acceptance (NRCAs).

- A certified mechanical ATT is required to perform the mechanical acceptance tests referenced by §120.5 and §160.3(d), and sign the Certificate(s) of Acceptance.
- Mechanical ATTs may perform the HERS field verification and diagnostic tests covered in the scope of Nonresidential Appendix NA2. These HERS tests are commonly performed by HERS Raters but can be performed by mechanical ATTs with the approval of the local jurisdiction.
- Other acceptance tests, such as those for covering processes and building envelope do not require a certified ATT.

More information on becoming certified and other information on ATTs can be found at http://www.energy.ca.gov/title24/attcp/.

14.1.2.3 Responsible Person

A certificate of acceptance must be signed by a *responsible person* who is licensed and eligible under Division 3 of the Business and Professions Code to take responsibility for the scope of work documented by the certificate of acceptance. In assuming responsibility for the work as a whole, the responsible person assumes responsibility for the acceptance testing work performed by his or her field technician, agent or employee.

The responsible person may perform the acceptance testing if qualified to do so. If qualified, the responsible person must complete and sign *both* the field technician's signature block *and* the responsible person's signature block on the Certificate of Acceptance document. (In addition to being licensed, a responsible person that conducts his or her own testing must also be a certified ATT if he or she is performing an acceptance test that requires a certified ATT.)

14.1.2.4 HERS Rater

Nonresidential Duct Leakage Testing. When single-zone, constant volume space-conditioning systems (1) serving less than 5,000 ft^2 of floor area and (2) having more than 25 percent of the system surface duct area are located in unconditioned space, duct sealing is prescriptively required by §140.4(l) for newly constructed buildings and §141.0(b)2C, D, and E for HVAC alterations. A HERS Verification of the duct system must be conducted by a certified HERS Rater to verify that the air distribution duct leakage of the system is within specifications required by the Energy Code. The HERS Verification is performed each duct system or on a sample (one in seven) of duct systems. For example, a series of buildings on a project site where the contractor is installing new HVAC systems (qualifying as indicated above) would require that the associated ducts be tested for leakage (limited to 15 percent of the system air volume). The installing contractor can perform and document the duct leakage test (NRCA-MCH-04a-A) and place seven of the completed NRCAs in a group. The group is then given to a HERS Rater, who selects one at random and performs the same acceptance test. The HERS Rater then records only the HERS Verification that they performed in the HERS data registry.

As an alternative for the contractor or builder (and approved by the enforcement agency), an ATT may perform and document the duct leakage test (NRCA-MCH-04b-A) and avoid using a HERS Rater. The ATT must record the duct test in the ATTCP database tracking system. In either case, each duct system must be tested. Multifamily Indoor Air Quality Testing. New for the 2022 Energy Code, mechanical ATTs may also perform the indoor air quality (IAQ) HERS Verifications specified in Reference Appendix NA1 (see Table 14.1-1) in place of HERS Raters for low-rise multifamily buildings.

Table 14.1-1: HERS Verification Eligible to be Performed by Certified Mechanical ATTs

HERS Verification	Verification Description	ATT-NRCA Form and Energy Code Reference
Dwelling-Unit Mechanical Ventilation Airflow – Continuous Operation	Verify that whole-building ventilation system complies with the airflow rate required by ASHRAE Standard 62.2.	NRCA-MCH-20a-A, and NRCA-MCH-20c-A Energy Code Reference: NA2.2.4.1
Dwelling-Unit Mechanical Ventilation Airflow – Intermittent Operation	Verify that whole-building ventilation system complies with the airflow rate required by ASHRAE Standard 62.2.	Forms and procedures posted with CEC Manufacturer Certification Program (https://www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment-6) Energy Code Reference: NA2.2.4.2
Kitchen Local Mechanical Exhaust Verification	Verify using certified performance rating data from the HVI Directory or the AHAM Directory for determining that the kitchen exhaust system complies with listed requirements.	NRCA-MCH-20a-A, and NRCA-MCH-20b-A Energy Code Reference: NA2.2.4.1.4

HERS Verification	Verification Description	ATT-NRCA Form and Energy Code Reference
Heat Recovery Ventilation (HRV) or Energy Recovery Ventilation (ERV) Rated Performance Verification	Verify that HRV or ERV system meets or exceeds the performance required for compliance.	NRCA-MCH-20a-A, and NRCA-MCH-20d-A Energy Code Reference: NA2.2.4.1.5
Building Envelope Air Leakage	The purpose of this test procedure is to measure the air leakage rate through a multifamily dwelling unit enclosure measured in cubic feet per minute	NRCA-MCH-21-A Energy Code Reference: NA2.3

Source: California Energy Commission

14.1.2.5 Commissioning Provider

A commissioning provider (also referred as a commissioning agent) is not defined by the Energy Code but is an industry term for a person who may be contracted by the owner to verify functional performance testing is conducted (among other responsibilities) to ensure proper performance at building turnover. Commissioning during construction is required by §120.8. In general, newly constructed nonresidential buildings with more than 10,000 square feet of conditioned floor area must comply with all of the requirements in §120.8 (full commissioning). Smaller buildings are required to complete just the design review phase of commissioning. The commissioning requirements in §120.8 do not apply to healthcare facilities, which have parallel requirements in Chapter 7 of the California Administrative Code (Title 24, Part 1), and do not apply to additions or alterations to existing buildings.

Although system commissioning and acceptance testing are related, not all projects that require acceptance testing will also require full commissioning. If a commissioning agent is part of the project team, they will often be present for functional performance testing of major building systems to verify the tests were completed and passed on behalf of the building owner. (Commissioning agents may instead perform acceptance testing themselves, and if this is the case, they may also need to be a certified ATT). See Nonresidential and Multifamily Compliance Manual Chapter 2 for more information regarding commissioning and commissioning agents.

14.1.2.6 Enforcement Agency

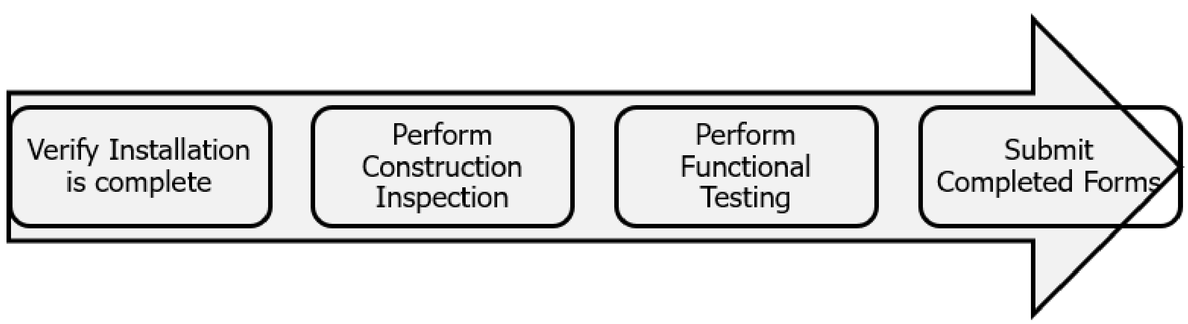
The certificate of acceptance must be submitted to the enforcement agency, typically at final inspection, to receive the certificate of occupancy. Many enforcement agencies will issue a provisional certificate of occupancy and allow the builder to fix or complete specific elements within a specified time frame. Enforcement agencies may not release a *final* certificate of occupancy unless the submitted certificate of acceptance demonstrates that the specified systems and equipment have been shown to perform in accordance with the applicable acceptance requirements.

The enforcement agency has the authority to require the field technician or responsible person to demonstrate competence to its satisfaction. When a certified ATT is required to complete an acceptance test, the enforcement agency may verify the ATT certification status through the ATTCP before issuing a certificate of occupancy. For details on how to do this most efficiently, see the Section 14.1.3 below. Please see Nonresidential and Multifamily Compliance Manual Chapter 2 for more information regarding enforcement agencies roles and responsibilities.

14.1.3 Acceptance Testing Process

See Nonresidential Multifamily Compliance Manual, Chapter 2 for a more complete discussion of the permitting process. As was shown in Figure 14.1-1, the acceptance testing is performed during the Operational Testing phase of permitted construction. The acceptance process itself follows four major steps as shown in Figure 14.1-2.

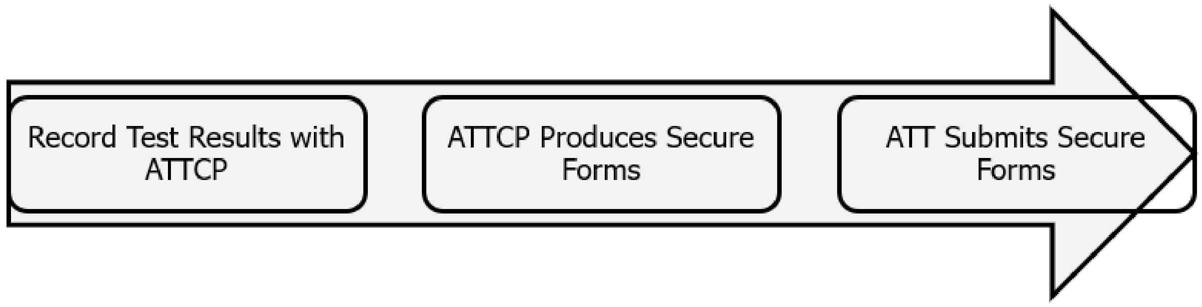
Figure 14.1-2: Steps in the Acceptance Testing Process



Source: California Energy Commission

The acceptance test process is slightly different when an ATT is required. As shown in Figure 14.1-3 the difference is in the use of the ATTCP when completing and submitting the completed forms (the final step in the general acceptance test process shown in Figure 14.1-2).

Figure 14.1-3: Final Step to Submit Completed Forms for the ATT Acceptance Testing Process



Source: California Energy Commission

Reviewing the acceptance requirements with the contractor before installation may help the process run smoothly. In some cases, performing tests immediately after installation is most economical, though this requires the complete installation of any associated systems and equipment necessary for proper system operation. Awareness of the acceptance test requirements can allow the contractor to identify a design or construction practice that would not comply with the Energy Code before equipment installation.

A technician or ATT assumes the responsibility for performing the required acceptance test requirement procedures in NA7 and reproduced on the Certificates of Acceptance for convenience. The CEC expects that the same technician or ATT that installed the efficiency feature will perform all the required acceptance tests for that feature, but this is not required. The technician or ATT who performs the acceptance test is responsible for identifying and remediating all performance deficiencies, repeating the test (if necessary) until the specified efficiency feature is performing in accordance with the acceptance test requirements.

Additionally, the CEC makes the following recommendations as a good industry practice, but are not required:

- When planning construction, consider costs of testing within subcontractor bids, scheduling time within the overall construction schedule and coordination with commissioning if required on the project.
- Purchasing sensors and equipment with calibration certificates often reduces the amount of time required for site calibration, which can lower overall costs.
- In some cases, performing tests immediately after installation or during set-up and commissioning is most economical, though this requires the complete installation of any associated systems and equipment necessary for proper system operation.

14.1.3.1 Verify Installation is Complete

The technician or ATT is responsible to verify that the efficiency feature is installed as indicated by the approved plans including the certificate of compliance. These plans, including the certificates of compliance, are approved by the enforcement agency during the permit application phase (see Figure 14.1-1). See Nonresidential and Multifamily Compliance Manual, Chapter 2 for a detailed explanation of the permitting process and roles and responsibilities. The certificates of compliance are completed by using the Virtual Compliance Assistant (VCA) Tool. The VCA Tool will indicate what acceptance tests are to be completed for each efficiency features at permit application phase. The technician or ATT must verify with the help of the responsible person what acceptances are to be performed and on what efficiency features. The technician or ATT is then to install the efficiency feature and ensure that it is operational and ready for acceptance testing.

14.1.3.2 Perform Construction Inspection

The construction inspection for acceptance testing is primarily a visual inspection of the installed efficiency feature (including records inspection), but may include some measurements. The construction inspection helps to ensure that the efficiency feature is present and capable of complying with the acceptance test requirements for the functional test.

The field technician or ATT performs the required construction inspection before functional testing as prescribed by the requirements in NA7 for each acceptance test.

14.1.3.3 Perform Functional Testing

The technician or ATT performs the functional testing requirements for each acceptance test as prescribed in NA7. The functional tests generally focus on the controls for the efficiency feature indicating a pass/fail for each setting. However, several functional tests do require specific measurements and calculations to pass, such the outdoor air volume delivered to a space.

14.1.3.4 Complete and Submit Certificate of Acceptance Forms

Once the efficiency feature passes the acceptance test requirements, the technician or ATT who performed the acceptance test completes the respective Certificate of Acceptance form and signs it to assert that the information recorded on the certificate is true and correct. In some instances, it may be beneficial for the technician or ATT to complete the Certificate of Acceptance form when the efficiency feature does not pass acceptance testing. This may help the technician or ATT identify the issues or errors that the efficiency feature is having that prevent it from passing. This information can be used to convey these issues to the responsible person for the project for remedy. A responsible person for the project must also sign the form to ensure that the performance of the scope of work specified by the Certificate of Acceptance and the test results provided by the field technician are complete.

As noted previously, the responsible person may also perform the field technician's responsibilities and, if so, must sign the field technician declaration on the certificate of acceptance. If the acceptance test requires a certified ATT, the responsible person must be a certified ATT to perform the acceptance test.

If the project includes duct leakage testing and a HERS Rater verification is to be performed, then the Certificate of Verification compliance documentation must be registered with the HERS Provider. See Nonresidential and Multifamily Compliance Manual, Chapter 2 for a more detailed discussion of HERS Verification process.

The completed and signed Certificate of Acceptance form must be submitted to the enforcement agency in accordance with the local laws, ordinances, regulations, or customs.

Building inspectors may review the forms during inspection. Inspectors can also verify that the ATT certification status through the ATTCP online certification lists. Finally, the inspector can verify that the completed form is valid by relying on the watermark provided by the ATTCP or by contacting the ATTCP to verify the form over the phone or via internet. Some ATTCPs provide a QR-Code for a quick and simple verification. ATTCP documents should not be accepted if completed by hand, completed electronically outside the ATTCP online interface, or fails to show the ATTCP logo and watermark.

14.2 Certificate of Acceptance

Certificate of acceptance (NRCA and LMCA) forms consist of worksheets to document the results of construction inspections and functional testing, as well as a signatory page. Table 14-1 shows the NRCA and LMCA documents and related references.

Naming Convention. The name of the compliance document can give you clues about the documents use. The NRCA prefix indicates a nonresidential certificate of acceptance which is used for nonresidential buildings and multifamily buildings with four or more habitable stories. The LMCA prefix indicates a low-rise multifamily certificate of acceptance which is used for multifamily buildings with up to three habitable stories. The next set of letters specifies the building component; for example, "LTI" indicates indoor lighting. The suffix will tell you whether a certified acceptance test technician "-A" or field technician "-F" is appropriate to perform the functional performance test. Remember that an ATT can act as a field technician, but a current ATT certification is required for someone to sign as an ATT.

Table 14.2-1: **Acceptance** *Documents*

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Envelope	NRCA-ENV-02-F LMCA-ENV-02-F Fenestration	§10-111 & §110.6(a)5	NA7.4.1	NONE

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Envelope	NRCA-ENV-02-F LMCA-ENV-02-F Window Films	§10-111 & §110.6(a)5	NA7.4.2	Made available to ATT
Envelope	NRCA-ENV-02-F LMCA-ENV-02-F Dynamic Glazing	§10-111 & §110.6(a)5	NA7.4.3	Made available to ATT
Envelope	NRCA-ENV-03-F LMCA-ENV-03-F Clerestories for PAF	§140.3(d)1 §170.2(e)2xii	NA7.4.4	Made available to ATT
Envelope	NRCA-ENV-03-F LMCA-ENV-03-F Interior and Exterior Horizontal Slats for PAF	§140.3(d)2 §170.2(e)2xii	NA7.4.5	Made available to ATT
Envelope	NRCA-ENV-03-F LMCA-ENV-03-F Interior and Exterior Lighting Shelves for PAF	§140.3(d)3 §170.2(e)2xii	NA7.4.6	Made available to ATT
Mechanical	NRCA-MCH-02-A Outdoor Air	§120.5(a)1 §160.3(d)1A	NA7.5.1.1 NA7.5.1.2	ATT

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Mechanical	NRCA-MCH-03-A Constant Volume, Single Zone, Unitary Air Conditioner and Heat Pump Systems	§120.1(c)2 §120.2 §120.5(a)2 160.3(d)1B	NA7.5.2	ATT
Mechanical	NRCA-MCH-04a-H LMCA-MCH-04a-H Duct Leakage	§120.5(a)3 §120.4(g) §141.0(b)2Dii §160.3(d)1C	NA7.5.3 NA1.9	NONE
Mechanical	NRCA-MCH-04b-A LMCA-MCH-04b-A Duct Leakage	§120.5(a)3, §120.4(g) §141.0(b)2Dii §160.3(d)1C	NA7.5.3 NA1.9	ATT
Mechanical	NRCA-MCH-05-A Economizer	§120.5(a)4 §140.4(e)	NA7.5.4	ATT
Mechanical	NRCA-MCH-06-A Demand Control	§120.1(c)4 §120.5(a)5	NA7.5.5	ATT
Mechanical	NRCA-MCH-07-A Supply Control	§120.5(a)6 §140.4(c)2B §140.4(c)2C	NA7.5.6	ATT
Mechanical	NRCA-MCH-08-A Valve Leakage	§120.5(a)8 §140.4(k)1§140.4(k)5 §140.4(k)6	NA7.5.7	ATT

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Mechanical	NRCA-MCH-09-A Supply Water	§120.5(a)9 §140.4(k)4	NA7.5.8	ATT
Mechanical	NRCA-MCH-10-A Hydronic System	§120.5(a)7 §140.4(k)1 §140.4(k)5 §140.4(k)6	NA7.5.9	ATT
Mechanical	NRCA-MCH-11-A Demand Shed Control	§110.12(b) §120.5(a)10	NA7.5.10	ATT
Mechanical	NRCA-MCH-12-A FDD Packaged Direct	§120.2(i) §120.5(a)11	NA7.5.11	ATT
Mechanical	NRCA-MCH-13-A (FDD AHU/ZTU	§120.5(a)12	NA7.5.12	ATT
Mechanical	NRCA-MCH-14-A Energy Storage	§120.5(a)13	NA7.5.13	ATT
Mechanical	NRCA-MCH-15-A Thermal Energy Storage	§120.5(a)14	NA7.5.14	ATT
Mechanical	NRCA-MCH-16-A Supply Air Temperature	§140.4(f) §120.5(a)15	NA7.5.15	ATT
Mechanical	NRCA-MCH-17-A Condenser Water Temp	This test is required if this control strategy is implemented. §120.5(a)16	NA7.5.16	ATT

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Mechanical	NRCA-MCH-18-A EMCS	§110.2(e) §120.2(h) §120.5(a)17 §130.4(b) §130.5(f) §150.0(k)	NA7.7.2	ATT
Mechanical	NRCA-MCH-19-A Occupancy Sensor	§120.2(e)3 §120.5(a)18	NA7.5.17	ATT
Mechanical	NRCA-MCH-20a-H LMCA-MCH-20a-H Multifamily Dwelling Inspection	§160.2(b)2Av §160.2(b)2Aix	NA7.18.1.1.1 NA2.2.2.1 NA2.2.3	ATT or HERS Rater
Mechanical	NRCA-MCH-20b-H LMCA-MCH-20b-H Multifamily Kitchen Exhaust	§160.2(b)2Bii §160.2(b)2Avi	NA7.18.1.1.1 NA2.2.4.1.3 NA2.2.4.1.4	ATT or HERS Rater
Mechanical	NRCA-MCH-20c-H LMCA-MCH-20c-H Multifamily IAQ System	§160.2(b)2Aivb §160.2(b)2Av	NA2.2.4.1.1	ATT or HERS Rater
Mechanical	NRCA-MCH-20d-H LMCA-MCH-20d-H Multifamily Dwelling HRV/ERV System	§160.2(b)2Biii §160.2(c)3Biva3 §170.2(c)3Biva3	NA7.18.1.1.2 NA2.2.4.1.5	ATT or HERS Rater

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Mechanical	NRCA-MCH-21-A LMCA-MCH-21-A Multifamily Dwelling Leakage	§120.1(b)2Aivb2	NA7.18.2.1 NA2.3.2 RESNET 380	ATT
Mechanical	NRCA-MCH-22-A LMCA-MCH-22-A Multifamily Duct Leakage	§160.2(b)2Av Table 170.2-G	NA7.18.4.1 NA7.18.4.2 NA7.5.4.2	ATT
Mechanical	NRCA-MCH-23-A LMCA-MCH-23-A Multifamily HRV/ERV Verification	§160.2(b)2Av Table 170.2-G	NA7.18.4.1 NA7.18.4.2 NA7.5.4.2	ATT
Indoor Lighting	NRCA-LTI-02-A LMCA-LTI-02-A Lighting Controls	§110.9(b) §130.1(c) §160.5(b)4C	NA7.6.2	ATT
Indoor Lighting	NRCA-LTI-03-A LMCA-LTI-03-A Automatic Daylighting Controls	§130.1(d) §160.5(b)4D	NA7.6.1	ATT

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Indoor Lighting	NRCA-LTI-04-A LMCA-LTI-04-A Demand Responsive Lighting and Receptacle Controls	§110.12(c) §110.12(e)	NA7.6.3 NA7.6.5	ATT
Indoor Lighting	NRCA-LTI-05-A LMCA-LTI-05-A Institutional Tuning Power Adjustment Factor	§140.6(a)2J, §170.2(e)Bx	NA7.6.4	ATT
Outdoor Lighting	NRCA-LTO-02-A LMCA-LTO-02-A Outdoor Lighting Acceptance Tests	§110.9(b) §130.2(c) §160.5(c)2	NA7.8	ATT
Covered Process, Systems, and Equipment	NRCA-PRC-01-F Compressed Air	§120.6(e)	NA7.13	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-02-F LMCA-PRC-02-F Kitchen Exhaust	§140.9(b)	NA7.11	NONE

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Covered Process, Systems, and Equipment	NRCA-PRC-03-F LMCA-PRC-03-F Garage Exhaust	§120.6(c)	NA7.12	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-04-F Refrigerated Warehouse – Motor Controls	§120.6(a)3 §120.6(a)7	NA7.10.2	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-05-F Refrigerated Warehouse – Evaporator	§120.6(a)4 §120.6(a)7	NA7.10.3.1	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-06-F Refrigerated Warehouse – Condenser Controls	§120.6(a)4 §120.6(a)7	NA7.10.3.2	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-07-F Refrigerated Warehouse – Compressor	§120.6(a)5 §120.6(a)7	NA7.10.4	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-08-F Refrigerated Warehouse – Underslab Heating	§120.6(a)2 §120.6(a)7	NA7.10.1	NONE

Component	Certificate of Acceptance Form Name	Energy Code Reference	Reference Nonresidential Appendix NA7	Required Certification
Covered Process, Systems, and Equipment	NRCA-PRC-12-F LMCA-PRC-12-F Elevator Lighting and Ventilation	§120.6(f)5, §160.7(a)	NA7.14	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-13-F Escalator Speed	§120.6(g)2	NA7.15	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-14-F Lab Exhaust	§140.9(c)	NA7.16	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-15-F Fume Hood	§140.4(c)4	NA7.17	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-16-F Adiabatic Condenser	§120.6(a)4C §120.6(a)7	NA7.10.3.3	NONE
Covered Process, Systems, and Equipment	NRCA-PRC-17-F FDD System and Steam Trap Strainer Installation Acceptance Test	120.6(j)	NA7.21	NONE

Source: California Energy Commission

14.3 Acceptance Testing Requirements

The following provides a summary of the acceptance testing requirements and testing procedures in the Energy Code for mechanical systems, lighting controls, building envelope, and covered processes.

Separate files providing detailed instructions on how to conduct acceptance tests are located at the CEC website: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency/.

14.3.1 Building Envelope Acceptance Testing Requirements

Envelope acceptance testing may be performed by any field technician however the installing contractor typically performs this testing.

Envelope acceptance testing is required for all buildings except single-family buildings per §110.6(a). These requirements apply to newly constructed buildings and to alterations.

The building envelope acceptance testing procedures are specified in Reference Nonresidential Appendix NA7.4.

The building envelope features that require acceptance testing include:

- NA7.4.1 Fenestration
- NA7.4.2 Window Films
- NA7.4.3 Dynamic Glazing
- NA7.4.4 Clerestories for Power Adjustment Factor
- NA7.4.5 Interior and Exterior Horizonal Slats for Power Adjustment Factor
- NA7.4.6 Interior and Exterior Light Shelves for Power Adjustment Factor

14.3.1.1 Fenestration, Window Films, and Dynamic Glazing Acceptance Testing NA7.4.1, NA7.4.2, and NA7.4.3

These tests are required for newly installed fenestration, window film, and dynamic glazing in new construction, additions, and alterations for all buildings except single-family residential per §110.6(a).

These fenestration products must be tested according to NA7.4 to verify that the National Fenestration Rating Council (NFRC) Label Certificate or California CEC Fenestration Certificate is provided for each fenestration product being installed. These certificates identify the thermal performance of the fenestration product (e.g. U-factor, solar heat gain coefficient, and visible transmittance).

This test also verifies that the thermal performance of installed fenestration products match the label certificate, energy compliance documentation, and plan specifications.

14.3.1.2 Daylighting Design Power Adjustment Factors Acceptance Testing NA7.4.4, NA7.4.5, and NA7.4.6

These tests are required to qualify for power adjustment factors for clearstory fenestration, interior and exterior horizontal slats, and interior and exterior light shelves in nonresidential, hotel/motel, multifamily common use areas per §140.3(d), §140.6(a)2L, §170.2(e)2xii, and §110.6(a)6.

These daylighting design features must be tested according to NA7.4 to verify that clerestory windows, interior and exterior horizontal slats, and interior and exterior light shelves meet the daylighting design requirements in the Energy Code when claiming a power adjustment factor (PAF) for lighting systems in nonresidential and hotel/motel buildings and multifamily building common use areas.

Spaces that have clerestory windows, horizontal slats, or light shelves, and compliant automatic daylighting controls may receive a power adjustment factor if the daylighting feature meets the design criteria in Energy Code.

14.3.2 Mechanical Systems Acceptance Testing Requirements

14.3.2.1 Outdoor Air

This test (NA7.5.1) ensures the constant volume air handling unit provides adequate outdoor air ventilation to the spaces served under all operating conditions. Systems requiring demand ventilation controls per §120.1(c)3 must conform to §120.1(c)4E regarding the minimum ventilation rate when the system is in occupied mode. Related acceptance tests for these systems include the following:

- NA7.5.2 Constant-Volume, Single-Zone, Unitary Air Conditioners and Heat Pump Systems Acceptance
- NA7.5.4 Air Economizer Controls Acceptance (if applicable)
- NA7.5.5 Demand-Controlled Ventilation Systems Acceptance (if applicable)Text

This test is restricted to certified Mechanical ATTs only, using Certificate of Acceptance NRCA-MCH-02-A.

14.3.2.2 HVAC and Heat Pumps

This acceptance test (NA7.5.2) is meant for constant volume, single zone, unitary (packaged and split) air conditioner and heat pump systems. This test verifies the components of a constant volume, single-zone, unitary air conditioner and heat pump system function correctly, including: thermostat installation and programming, supply fan, heating, cooling, and damper operation. Testing of the economizer, outdoor air ventilation, and demand-controlled ventilation are located in the following sections of the Reference Appendices:

- NA7.5.1.2 Constant Volume System Outdoor Air Acceptance
- NA7.5.4 Air Economizer Controls (if applicable)

- NA7.5.5 Demand Control Ventilation (DCV) Systems (if applicable)

This test is restricted to certified Mechanical ATTs only, using Certificate of Acceptance NRCA-MCH-03-A.

14.3.2.3 Duct Leakage

This test (NA7.5.3) verifies all duct work associated with all nonexempt constant volume, single-zone HVAC units (in other words, air conditioners, heat pumps, and furnaces) meet the material, installation, and insulation R-values per §120.4(a) and leakage requirements outlined either in §120.4(g)1 for new duct systems or §141.0(b)2D and §141.0(b)2Eii) for existing duct systems.

This test may either be verified by a HERS Rater (sampling permitted) with the technician testing each installation and using NRCA-MCH-04a-H to record the results or performed by a certified mechanical ATT (no sampling permitted) using NRCA-MCH-04b-A and recording it with an ATTCP.

14.3.2.4 Economizer DOAS HRV ERV

This test (NA7.5.4) is restricted to certified mechanical ATTs and is intended to verify Energy Code compliance for nonresidential and hotel/motel (see NRCA-MCH-23-A for multi-family) buildings with newly installed economizers, dedicated outdoor air system (DOAS), Heat Recovery Ventilation (HRV) systems, and energy recovery ventilation (ERV) system. Economizers must be certified to the California CEC in compliance with JA6.3.

Submit one Certificate of Acceptance (NRCA-MCH-05-A) for each economizer, DOAS, HRV, or ERV system that must demonstrate compliance with the Energy Code. For direct Energy Code reference see JA6.3, NA7.5.4, §140.4(e), §120.5(a)4, and §160.3(d)1D.

Functionally testing an air economizer cycle verifies that an HVAC system uses outdoor air to satisfy space-cooling loads. There are two types of economizer controls: stand-alone packages and DDC controls. The stand-alone packages are commonly associated with small unitary rooftop HVAC equipment. DDC controls are typically associated with built-up or large packaged air handling systems.

Cooling fan systems greater than 33,000 Btu/hr may use an economizer to comply with prescriptive requirements in §140.4(e). Air economizers must be able to provide 100 percent of the design supply air with outside air; water economizers must be able to provide 100 percent of the design n cooling load at 50°F dry-bulb and 45°F wet-bulb.

14.3.2.5 Demand Ventilation Control

The purpose of the test (NA7.5.5) is to verify that systems required to employ demand controlled ventilation (refer to §120.1(c)3) can vary outside ventilation flow rates based on maintaining interior carbon dioxide (CO_2) concentration setpoints. Demand Ventilation Control (DVC) refers to an HVAC system's ability to reduce outdoor air ventilation flow below design values when the space served is at less than design occupancy.CO_2 is a good indicator of occupancy load and is the basis used for modulating ventilation flow rates.

DVC complying with §120.1(d)4 are required for a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 square feet (40 square feet or less per person) if the ventilation system serving the space has one or more of the following:

- an air economizer, modulating outside air control, or
- design outdoor airflow rate > 3,000 cfm (§120.1(d)3).

This acceptance test is limited to certified mechanical ATTs using NRCA-MCH-06-A to verify that a system required to employ a DVC can vary outside air ventilation flow rates based on maintaining interior carbon dioxide (CO2) concentration setpoints in compliance with §120.1(d)4. NRCA-MCH-02-A must be completed either prior to or concurrently with this acceptance test for the space in which the CO2 monitor is located. One NRCA-MCH-06-A must be completed for each CO2 sensor in the system that must demonstrate compliance. For direct Energy Code reference see §120.1(d)3, §120.1(d)4, NA7.5.1, and NA7.5.5.

14.3.2.6 Supply Fan Controls

The purpose of the test (NA7.5.6) is to ensure that the supply fan in a variable air volume application modulates to meet system airflow demand. In most applications, the individual variable air valve (VAV) boxes serving each space will modulate the amount of air delivered to the space based on heating and cooling requirements. As a result, the total supply airflow provided by the central air handling unit must also vary to maintain sufficient airflow through each VAV box. Airflow is typically controlled using a variable frequency drive (VFD) to modulate supply fan speed and vary system airflow. The most common strategy for controlling the VFD is to measure and maintain static pressure within the duct.

This test is restricted to a certified mechanical ATT using NRCA-MCH-07-A to verify that the supply fan speed in a variable air volume system modulates to meet system airflow demand. NRCA-MCH-07-A can be performed in conjunction with NRCA-MCH-02-A Outdoor Air Acceptance since testing activities overlap.

14.3.2.7 Valve Leakage test

This test (NA7.5.7) ensures that control valves serving variable flow systems are designed to withstand the pump pressure over the full range of operation. Valves with insufficient actuators will lift under certain conditions causing water to leak and loss of flow control. This test applies to the variable flow systems covered by §140.4(k)1 chilled and hot-water variable flow systems, §140.4(k)2 chiller isolation valves, §140.4(k)3 boiler isolation valves, and §140.4(k)5 water-cooled air conditioner and hydronic heat pump systems.

This test is restricted to certified mechanical ATTs using NRCA-MCH-08-A to ensure that control valves serving variable flow systems can withstand the pump pressure over the full range of operation. Related acceptance tests for these systems include NA7.5.9 Hydronic System Variable Flow Controls Acceptance Testing time will be greatly reduced if these acceptance tests are done simultaneously.

14.3.2.8 Water Temperature Reset

This test (NA7.5.8) ensures that both the chilled water and hot water supply temperatures are automatically reset based on either building loads or outdoor air temperature, as indicated in the control sequences. Many HVAC systems are served by central chilled and heating hot water plants. The supply water operating temperatures must meet peak loads when the system is operating at design conditions. As the loads vary, the supply water temperatures can be adjusted to satisfy the new operating conditions. Typically the chilled water supply temperature can be raised as the cooling load decreases, and heating hot water supply temperature can be lowered as the heating load decreases.

This requirement only applies to chilled and hot water systems that are not designed for variable flow and that have a design capacity greater than or equal to 500 kBtuh (thousand BTU’s per hour), according to §140.4(k)4.

This test is restricted to certified mechanical ATTs using NRCA-MCH-09-A to ensure that both the chilled water and hot water supply temperatures are automatically reset based on either building loads or outdoor air temperature, as indicated in the control sequences. (§140.4(k)4).

Note the following exception: Hydronic systems that use variable flow to reduce pumping energy. (§140.4(k)1)

14.3.2.9 Variable Flow Control

This test (NA7.5.9) is for all hydronic variable flow chilled water and water-loop heat pump systems with total circulating pump power larger than 5 hp shall vary system flow rate by modulating pump speed using either a variable frequency drive (VFD) or equivalent according to §140.4(k)6. Pump speed and flow must be controlled as a function of differential pressure, and pump motor demand must be no more than 30 percent design wattage at 50 percent design flow.

As the loads within the building fluctuate, control valves should modulate the amount of water passing through each coil and add or remove the desired amount of energy from the air stream to satisfy the load. In the case of water-loop heat pumps, each two-way control valve associated with a heat pump closes when not operating. The purpose of the test is to ensure that, as each control valve modulates, the pump variable frequency drive (VFD) responds accordingly to meet system water flow requirements.

This test is restricted to certified mechanical ATTs using NRCA-MCH-10-A to ensure that hydronic pump speed varies with building heating and cooling loads.

The related acceptance tests for this system is NA7.5.7 Valve Leakage Test – NRCA-MCH-08-A (if applicable)

14.3.2.10 Demand Shed Control

This test (NA7.5.10) is used if the building has DDC to the zone level, the HVAC control system must be capable receiving a Demand Response Signal and automatically initiating a control strategy once the signal is received. This acceptance test confirms that the HVAC control system is programmed so that it is capable of initiating the control strategy specified in §110.12(b). That is, modify the temperature setpoints in non-critical zones up by 4°F if the system is cooling the space or down by 4°F if the system is heating the space. The building owner or occupant has the option of selecting another control strategy than the one tested here if they choose to enroll in a demand response program.

This test is restricted to certified mechanical ATTs using NRCA-MCH-11-A to ensure that the central demand shed sequences have been properly programmed into the DDC system.

14.3.2.11 FDD – Packaged Units

The purpose of this test (NA7.5.11) is to verify proper fault detection and diagnostic (FDD) reporting for automated fault detection and diagnostics systems for packaged DX units. Automated FDD systems ensure proper equipment operation by identifying and diagnosing common equipment problems such as temperature sensor faults, low airflow or faulty economizer operation. FDD systems help to maintain equipment efficiency closer to rated conditions over the life of the equipment.

This test is restricted to certified mechanical ATTs use NRCA-MCH-12-A and is recommended to be performed simultaneity with NRCA-MCH-02-A (Outside Air) and NRCA-MCH-05-A (Air Economizer Controls).

14.3.2.12 AHU and Zone Terminal FDD

The purpose of this test (NA7.5.12) is to verify proper FDD reporting for air handling unit (AHU) and zone terminal unit (ZTU) systems. Fault detection and diagnostics can also be used to detect common faults with air handling units and zone terminal units. Many FDD tools are standalone software products that process trend data offline. Maintenance problems with built-up air handlers and variable air volume boxes are often not detected by energy management systems because the required data and analytical tools are not available. Performing the FDD analysis within the distributed unit controllers is more practical because of the large volume of data.

The acceptance tests are designed to verify that the system detects common faults in air handling units and terminal units. FDD systems for air handling units and zone terminal units require DDC controls to the zone level. Successful completion of this test provides a compliance credit when using the performance approach. An FDD system that does not pass this test may still be installed, but no compliance credit will be given.

This test is restricted to certified mechanical ATTs use NRCA-MCH-13-A to verify that the system detects common faults in air handling units and zone terminal units.

14.3.2.13 Energy Storage for HVAC

This test (NA7.5.13) verifies proper operation of distributed energy storage DX systems. Distributed energy systems reduce peak demand by operating during off peak hours and storing cooling, usually in the form of ice. During peak cooling hours the ice is melted to avoid compressor operation.

This acceptance test applies to direct expansion (DX) system with distributed energy storage (DES/DXAC). These acceptance requirements are in addition to those for those other systems or equipment such as economizers or packaged equipment. This acceptance test was developed by AEC for Distributed Energy Storage for Direct-Expansion Air Conditioners, January 27, 2005, and is directly referenced by the 2022 Building Energy Efficiency Standards.

This test is restricted to certified mechanical ATTs use NRCA-MCH-14-A to verify that the system conforms with the Energy Code requirements.

14.3.2.14 Thermal Energy Storage

This test (NA7.5.14) verifies proper operation of thermal energy storage (TES) systems. TES systems reduce energy consumption during peak demand periods by shifting energy consumption to nighttime. Operation of the thermal energy storage compressor during the night produces cooling energy, which is stored in the form of cooled fluid or ice in tanks. During peak cooling hours the thermal storage is used for cooling to prevent the need for chiller operation.

The test will ensure that the TES system is able to charge the storage tank during off-peak hours and conversely discharge the storage tank during on peak hours. Since the chiller may operate more efficiently at night when ambient temperatures are lower, the system may save cooling energy in some climate zones. This acceptance test is intended for Thermal Energy Storage (TES) Systems that are used in conjunction with chilled water air conditioning systems.

This test is restricted to certified mechanical ATTs use NRCA-MCH-15-A to verify that the system conforms with the Energy Code requirements.

14.3.2.15 Supply Air Temperature Reset Controls

The purpose of the test (NA7.5.15) is to ensure that the supply air temperature in a constant or variable air volume application serving multiple zones, according to Section 140.4(f), modulates to meet system heating and cooling loads. Space conditioning systems must have zone level controls to avoid reheat, re-cool, and simultaneous cooling and heating [§140.4(d)]; or must have controls to reset supply air temperature (SAT) by at least 25 percent of the difference between the design supply-air temperature and the design room air temperature [§140.4(f)2]. Air distribution systems serving zones with constant loads must be designed for the air flows resulting from the fully reset (e.g. lowest/highest) supply air temperature. The requirements for SAT reset apply to both CAV and VAV systems. Exceptions include:

- Systems with specific humidity needs for exempt process loads (computer rooms or spaces serving only IT equipment are not exempt).
- Zones served by space conditioning systems in which at least 75 percent of the energy for reheating, or providing warm air in mixing systems, is provided from a site-recovered or site-solar energy source.
- Systems in which supply air temperature reset would increase overall building energy use.
- Systems with controls to prevent reheat, re-cool, and/or simultaneous cooling and heating.

Supply air temperature may be reset in response to building loads, zone temperature, outside air temperature, or any other appropriate variable.

This test is restricted to certified mechanical ATTs use NRCA-MCH-16-A to verify that the supply air temperature modulates to meet system temperature setpoint(s).

14.3.2.16 Condenser Reset Controls

The intent of the test (NA7.5.16) is to verify that the condenser water supply (entering condenser water) temperature is automatically reset as indicated in the control sequences; based upon building loads, outdoor air wet-bulb temperature, or another appropriate control variable. All cooling tower system components (e.g. fans, spray pumps) should operate per the control sequences to maintain the proper condenser water temperature and pressure set points.

Chilled water plants serve many buildings, responding to the varying cooling loads throughout the year. As the loads vary, the chilled water supply temperatures adjust to satisfy the new operating conditions. Often, water-cooled chilled water plants can decrease the condenser water temperature in times of low cooling load. This occurrence can be demonstrated by running the cooling tower fans at a higher speed, staging on additional fans, or varying water distribution across the tower fill by closing and opening bypass valves. As a result, the cooling tower produces an energy penalty, however the chiller efficiency and the overall plant efficiency improves.

The purpose of this test is not to evaluate whether a particular control sequence is the most appropriate for the facility, but whether the system follows the intended control sequence. This test is restricted to certified mechanical ATTs use NRCA-MCH-17-A to ensure that the condenser water supply temperature is automatically reset as indicated in the control sequence(s).

14.3.2.17 EMCS System Acceptance

The purpose of this acceptance test (§120.5[a]17 and §160.3[d]1P) is to ensure that when an energy management control system (EMCS) is installed for the purpose of compliance with the Building Energy Efficiency Standards (Standards), it is properly installed, operational, and is in compliance with each relevant requirement in the Standards.

This test is restricted to certified mechanical ATTs use NRCA-MCH-18-A to ensure that when an energy management control system (EMCS) is installed for the purpose of compliance with the Energy Code, it is properly installed, operational, and is in compliance with each relevant requirement in the Standards.

14.3.2.18 Occupied Standby

This test (NA7.5.17) verifies that an installed occupancy sensor is functional and in compliance with the approved project designs and Energy Code. The technician must submit one Certificate of Acceptance for each occupancy sensor installed.

This test is restricted to certified mechanical ATTs use NRCA-MCH-19-A to ensure that the occupancy sensor is functional and in compliance with the design and with the Energy Code.

14.3.2.19 Dwelling Ventilation

This test (NA7.18.1 and NA2.2) can be performed by a certified mechanical ATT or uncertified technician and HERS Rater to verify that the continuous ventilation airflow (supply, exhaust, or balanced) system, the kitchen exhaust fan, and/or the heat recovery ventilations (HRV) or energy recovery ventilation (ERV) system conforms to the requirements of the Energy Code and ANSI/ASHRAE Standards 62.2-2016. If using supply-only or exhaust-only ventilation, Certificate of Acceptance NRCA-MCH-21-H must be completed prior to beginning this acceptance test.

This test is not restricted to certified mechanical ATTs if a HERS Rater is used as a verification for an uncertified technician to perform the same test and the verification is registered with a HERS Provider. Alternatively, these same forms can be used by a mechanical ATT without need of a HERS Rater.

NRCA-MCH-20a-H must be completed (once) for all of the subsequent forms for dwelling ventilation requirements. NRCA-MCH-20b-H is used to verify the kitchen range hood complies with the Energy Code requirements. NRCA-MCH-20c-H is used to verify the indoor air quality ventilation systems complies with the Energy Code requirements. NRCA-MCH-20d-H is used to verify HRV or ERV (if installed) systems comply with the Energy Code requirements.

This acceptance test is intended for multifamily dwelling units where CONTINUOUS ventilation is used. The Executive Director may approve INTERMITTENT mechanical ventilation systems, devices, or controls for use for compliance with field verification and diagnostic testing requirements for mechanical ventilation airflow, subject to a manufacturer providing sufficient evidence to the Executive Director that the installed mechanical ventilation systems, devices, or controls will provide at least the minimum ventilation airflow required by the Standards, and subject to consideration of the manufacturer's proposed field verification and diagnostic test protocol for the ventilation system(s). Ventilation airflow of systems with multiple operating modes shall be tested in all modes designed to comply with the required ventilation airflows. Approved systems, devices, or controls, and field verification and diagnostic test protocols for intermittent mechanical ventilation systems will be listed in directories published by the CEC (NA2.2.4.1.3).

14.3.2.20 Multifamily Envelope Leakage

This acceptance test (NA7.18.2) is used to verify that the envelope leakage rate for multifamily dwelling units conforms to the requirements of the Energy Code.

This test is not restricted to certified mechanical ATTs if a HERS Rater is used as a verification for an uncertified technician to perform the same test and the verification is registered with a HERS Provider. Alternatively, this same form can be used by a mechanical ATT without need of a HERS Rater.

NRCA-MCH-21-H must be completed for each dwelling unit using a supply-only or exhaust-only ventilation system to verify that the envelope leakage conforms to the requirements of the Energy Code §120.1(b)2Aivb2 and Nonresidential Reference Appendices NA7.18.2, NA2.3, ANSI/RESNET/ICC 380-2016, and ASTM E779-10 (2010). The certified mechanical ATT or technician and HERS Rater is required to complete this compliance certificate prior to completing NRCA-MCH-20-H.

See section 14.3.2.19 regarding intermittent ventilation systems.

14.3.2.21 System Duct Leakage

The objective of this procedure (NA7.18.3) is to verify the leakage of a new central ventilation duct system(s) (Section 160.2(b)2Ci) that serve multiple dwelling units and provides continuous airflows or are part of a balanced ventilation system to meet the requirements specified in Sections 160.2(b)2Aiv or 160.2(b)2Av. This compliance document (NRCA-MCH-22-A) is used to record the results of one system duct leakage test performed. These test procedures are based on ATSM 1554 Method D – Total duct leakage test. This test may only be performed by a certified mechanical ATT.

14.3.2.22 HRV or ERV Verification

The objective of this acceptance test is to verify the HRV or ERV requirement in multifamily buildings for compliance with Section 170.2(c)3Bvb, a central ERV/HRV serving multiple dwelling units. This test may only be performed by a certified mechanical ATT.

14.3.3 Lighting Controls Acceptance Testing Requirements

Lighting controls acceptance testing must be performed by a certified lighting controls ATT to certify the indoor and outdoor lighting controls serving the building, area, or site meet the acceptance requirements.

Lighting controls acceptance testing is required for all installed lighting controls in nonresidential buildings and hotel/motel buildings per §130.4(a), and for multifamily building common use areas per §160.5(e). These requirements apply to newly constructed buildings and to alterations. For alterations where lighting controls are added to control 20 or fewer luminaires, acceptance testing is not required.

The lighting controls acceptance testing procedures are specified in Reference Nonresidential Appendix NA7.6.

The lighting controls that require acceptance testing include:

- NA7.6.1 Automatic daylighting controls
- NA7.6.2 Shutoff controls
- NA7.6.3 Demand responsive lighting controls
- NA7.6.4 Lighting systems receiving institutional tuning power adjustment factor
- NA7.6.5 Demand responsive controls for controlled receptacles
- NA7.8 Outdoor lighting controls

14.3.3.1 Automatic Daylighting Controls Acceptance Testing NA7.6.1

This test is required when automatic daylighting controls are installed in nonresidential and hotel/motel buildings or in multifamily building common use areas. General lighting within a daylit zone must be controlled by automatic daylighting controls per the requirements of §130.1(d) and §160.5(b)4D.

Automatic daylighting controls must be tested according to NA7.6.1 to verify that the automatic daylighting controls are installed and that they automatically adjust electric lighting power in response to available daylighting in the space.

14.3.3.2 Shutoff Controls Acceptance Testing NA7.6.2

All installed indoor lighting must be controlled by shutoff controls per §130.1(c) and §160.5(b)4C. Shutoff controls acceptance testing ensure that occupant sensing controls and automatic time switch controls that are installed are functioning according to these requirements.

Automatic shutoff controls must be tested according to NA7.6.2 to verify that occupant sensing controls and automatic time switch controls are functioning properly to achieve the desired lighting controls.

Occupant sensing control acceptance testing verifies that the controls are installed per manufacturer’s instructions and that the occupant sensing control dims or turns lighting on or off according to occupancy in the space.

The automatic time switch controls acceptance testing verifies that indoor lighting controlled by an automatic time switch control turns lighting on and off according to a programmed schedule and that manual override controls turn lighting on during scheduled off periods.

14.3.3.3 Demand Responsive Lighting Controls Acceptance Testing NA7.6.3

This test is required when demand responsive lighting controls are installed in nonresidential and hotel/motel buildings, and in multifamily building common areas per the requirements of §130.1(e), §160.5(b)4E, and §110.12. Demand responsive lighting controls are required for:

- Newly constructed buildings with general lighting power of 4,000 watts or greater
- Lighting alterations and additions with general lighting power of 4,000 watts or greater

Demand responsive lighting controls must be tested according to NA7.6.2 to verify that demand responsive controls can reduce lighting power of the building to at least 85 percent of full power. The test also confirms that the lighting system produces a uniform level of illumination during a demand response event.

14.3.3.4 Institutional Tuning Power Adjustment Factor Acceptance Testing NA7.6.4

This test is required when institutional tuning controls are installed to qualify for a power adjustment factor in nonresidential and multifamily common use area lighting systems per §140.6(a)2J or §170.2(e)2Bx. Institutional tuning is the process of adjusting the maximum light output of lighting systems to support visual needs or save energy. Institutional tuning differs from personal tuning in that the control strategy is implemented at the institutional rather than the individual user level, and maximum light level adjustments are available only to authorized personnel.

Institutional tuning must be tested according to NA7.6.4 to verify that the institutional tuning controls limit the maximum light output or power draw of the controlled lighting to 85 percent or less of full light output or full power draw.

Completion of this acceptance test certifies that lighting systems receiving the institutional tuning power adjustment factor (PAF) comply with §140.6(a)2J or §170.2(e)2Bx, and NA7.6.4.

14.3.3.5 Demand Responsive Controls for Controlled Receptacles NA7.6.5

This test is required when demand responsive controls for controlled receptacles are installed in nonresidential and hotel/motel buildings, and in multifamily building common use areas per the requirements in §130.5(d), §160.6(e), and §110.12(e). Demand responsive controls for controlled receptacles are required in when the following conditions are met:

1. Controlled receptacles are required per §130.5(d) or §160.6(e)
2. The building is required to have demand responsive lighting controls per §110.12(c)

Demand responsive controls for controlled receptacles must be tested according to NA7.6.5 to verify that demand responsive controls can turn off all loads connected to controlled receptacles when a demand response signal is received.

14.3.3.6 Outdoor Lighting Controls Acceptance Testing NA7.8

This test applies to outdoor lighting controls which include photocontrols, motion sensors, astronomical time-switch controls, and scheduling controls for outdoor lighting systems per the requirements of §130.2 and §160.5(c). These controls are required for nonresidential, hotel/motel, and multifamily buildings.

Outdoor lighting controls must be tested according to NA7.8 to verify that all outdoor lighting regulated by §130.2(c) and §160.5(c) is controlled by a motion sensor, photocontrol, astronomical time-switch control, and automatic scheduling control, as required.

14.3.4 Covered Process Acceptance Testing Requirements

Covered process acceptance testing may be performed by any field technician however the startup technician typically performs this testing.

Covered process acceptance testing is required for all covered process specified in §120.6 and §140.9. These requirements apply to newly constructed buildings and to alterations.

The covered process acceptance testing procedures are specified in Reference Nonresidential Appendix NA7.10 through NA7.20.

The covered processes that require acceptance testing include:

- NA7.10 Refrigerated warehouse refrigeration systems
- NA7.11 Commercial kitchen exhaust systems
- NA7.12 Parking garage ventilation systems
- NA7.13 Compressed air systems
- NA7.14 Elevator lighting and ventilation controls
- NA7.15 Escalator and moving walkway controls
- NA7.16 Lab exhaust ventilation systems
- NA7.17 Fume hood automatic sash closure
- NA7.19 Steam trap fault detection
- NA7.20 Transcritical CO_2 systems

14.3.4.1 Refrigerated Warehouse Acceptance Testing NA7.10

New refrigerated warehouses, or new refrigeration system serving a refrigerated warehouse require acceptance testing per §120.6(a). The following equipment and systems must be tested to verify that the system operates according to Energy Code requirements.

- Electric resistance underslab heating systems must be tested according to NA7.10.1 to verify that any heated slab that uses an electric resistance heating system is thermostatically controlled to prevent excess heat from entering the refrigerated space and that its load is shed during the summer on-peak period defined by the electric utility provider, as required per Energy Code. The test verifies that the electric resistance heater is controlled according to the underfloor temperature and is forced off during the summer on-peak period.

- Evaporators and evaporative fan motor controls must be tested according to NA7.10.2 to verify that evaporator fans modulate speed in response to space temperature or humidity. Evaporator fan motor controls are required for new, or altered refrigerated warehouses that are 3,000 square feet or more and refrigerated spaces with a sum total of 3,000 square feet that are served by the same refrigeration system
- Evaporative, air-cooled, and adiabatic condensers must be tested according to NA7.10.3 to verify that the condensing temperature setpoint of the condenser is reset in response to ambient dry-bulb or wet-bulb temperature, condenser fan speed is continuously variable, condenser fans are controlled in unison, and that the minimum condensing temperature control setpoint meets specifications. Condenser fan motor controls are required on any new evaporative, air-cooled, or adiabatic condensers installed on new refrigeration systems.
- Variable speed compressors must be tested according to NA7.10.4 to verify that variable speed compressor controls modulate compressor speed in response to the refrigeration load. Compressor variable speed controls are required on any new refrigeration systems.

14.3.4.2 Commercial Kitchen Exhaust System Acceptance Testing NA7.11

New commercial kitchens, or new commercial kitchen exhaust systems with Type I and Type II kitchen hood exhausts with a total exhaust airflow rate greater than 5,000 cfm require acceptance testing per §140.9(b).

All Type I exhaust hoods must be tested according to NA7.11 to verify that the exhaust airflow rate meets Energy Code requirements, and that demand control ventilation, and make up air systems are functional.

14.3.4.3 Parking Garage Ventilation Acceptance Testing NA7.12

All newly installed parking garage ventilation systems with carbon monoxide control must be tested per §120.6(c).

Airside economizers must be tested according to NA7.12 to verify that the airside economizers function properly and carbon monoxide levels are maintained in a healthy range.

14.3.4.4 Compressed Air System Acceptance Testing NA7.13

All new compressed air systems, and all additions or alterations of compressed air systems, where the total combined online horsepower of the compressor(s) is 25 horsepower or more, must be tested per §120.6(e).

Compressed air system controls must be tested according to NA7.13 to verify that compressed air system controls and monitoring systems are set up in a compliant manner. A compliant system will use the most efficient combination of compressors, given the current air demand as measured by a sensor. This test ensures that short-cycling or blow-off does not occur. For new compressed air systems, the trim compressors are the only compressors that can be partially loaded. All base compressors must be either fully loaded or off by the end of the test.

14.3.4.5 Elevator Lighting and Ventilation Controls Acceptance Testing NA7.14

This test is required for newly installed elevators in nonresidential, multifamily, and hotel/motel buildings per §120.6(f).

Elevator lighting and ventilation controls must be tested according to NA7.14 to verify that shut off controls installed in an elevator cab turn lighting and ventilation fans off when the elevator is not occupied for more than 15 minutes, and on when elevator cab operation resumes.

The control system must also be able to detect occupancy, and keep the lighting and ventilation fan on, in the event that someone is occupying the elevator cabin and the elevator conveyance or doors malfunction.

14.3.4.6 Escalator and Moving Walkway Controls Acceptance Testing NA7.15

This test is required for newly installed escalators and moving walkways located in airports, hotels, and transportation function areas per §120.6(g).

Escalator and moving walkway controls must be tested according to NA7.15 to verify that the speed of the escalator or moving walkway slows when unoccupied and speeds up when passengers approach. The control system must be able to detect occupancy and approaching pedestrians in either direction.

14.3.4.7 Lab Exhaust Ventilation System Acceptance Testing NA7.16

This test is required for newly installed laboratory and factory exhaust systems with airflow greater than 10,000 cfm per §140.9(c).

Lab exhaust and ventilation controls must be tested according to NA7.16 to verify that the design and installation of the laboratory exhaust system, including wind speed and contaminant controls, are installed and in operation to limit excessive energy use, without sacrificing operator safety.

14.3.4.8 NA7.17 Fume Hood Automatic Sash Closure Acceptance Testing NA7.17

This test is required for newly constructed laboratory fume hoods with vertical only sashes, located in fume hood intensive laboratories per §140.9(c)4.

Fume hood automatic sash closure controls must be tested according to NA7.17 to verify that the manual and automated controls of the fume hood and sash operate in compliance with the Energy Code and the enforcement agency approved design.

14.3.4.9 Steam Trap Fault Detection Acceptance Testing NA7.19

This test is required for steam traps in new industrial facilities and new steam traps added to support new, non-replacement, process equipment in existing industrial facilities where the following conditions are met:

1. The installed steam trap operating pressures is greater than 15 psig
2. The total combined connected boiler input rating is greater than 5 million Btu per hour

Requirements for steam trap fault detection are included in §120.6(i).

Steam trap fault detection must be tested according to NA7.19 to verify that the fault detection system is installed, programmed, and operating in compliance with the Energy Code.

14.3.4.10 Transcritical CO_2 Systems Acceptance Testing NA7.20

This test is required for all new refrigerated warehouses and retail food or beverage stores with transcritical CO_2 refrigeration systems, or for newly installed transcritical CO_2 refrigeration systems serving refrigerated warehouses and retail food or beverage stores per §120.6(a) and §120.6(b).

Transcritical CO_2 refrigeration systems must be tested according to NA7.20 to verify proper operation of gas cooler control, including variable speed fan operation and variable setpoint control logic, which are both important elements of floating head pressure control, with the intent to operate with the lowest total system energy (considering both compressors and gas cooler fan power) through the course of the year.

14.4 Changes to Acceptance Test Requirements for the 2022 Energy Code

14.4.1 Building Envelope §110.6:

- No changes

14.4.2 Mechanical Systems and Equipment §120.5:

- New Acceptance Test:
    - Central Ventilation System Duct Leakage Acceptance for multifamily projects
    - Central Ventilation System HRV or ERV for multifamily ptojects

- Major Modifications:
    - All acceptance test form were updated to comply with accessibility requirements.
    - Acceptance test for DOAS, HRV, ERV added to economizer acceptance test (NA7.5.4)
    - ATT as an alternative to the technician-HERS Rater verification process was added as an option to four acceptance tests for multifamily low-rise projects:
        - Dwelling Unit Ventilation
            - Indoor air quality airflow (supply, exhaust, or balanced) system
            - Kitchen exhaust fan
            - DOAS, HRV, or ERV system
        - Multifamily Envelope Leakage
- Minor Clarifications
    - Revised references to reflect the new multifamily section in the Energy Code.

14.4.3 Lighting Controls

- New Acceptance Tests:
    - Demand responsive controlled receptacles (NA7.6.5, NRCA-LTI-04-A)
- Major Modifications:
    - Lighting controls installed in multifamily common use areas require acceptance testing per §160.5(e).
    - An alternative partial daylight test has been added to address stakeholder concerns with the feasibility of using the current partial daylight test in all conditions, particularly in daylit spaces with dark glazing or small window areas (NA7.6.1.4).
    - An alternative demand responsive controls testing procedure has been added to allow testing for the entire facility at once provided that the lighting load is disaggregated from other end use loads (NA7.6.3.2.3).
    - A new testing procedure has been added for multi-zone occupant sensing controls in offices larger than 250 square feet (NA7.6.2.4).
    - Addition of sampling procedures for outdoor photocontrols acceptance testing (NA7.8.3.2).
- Minor Clarifications:

  - Added specific items to verify during the construction inspection to improve clarity and align with Energy Code requirements
  - Reorganize testing procedure steps to improve clarity and align testing procedures with how testing is conducted in the field.
  - The institutional tuning acceptance testing procedures were relocated to NA7.6.4 from NA7.7.5.
  - Added clarification on testing procedures for partial on, partial off, and vacancy sensing controls.

14.4.4 Covered Process Systems and Equipment

- New Acceptance Tests:
  - Transcritical CO_2 system acceptance for refrigerated warehouses and commercial refrigeration (NA7.20.1).
  - Compressed air system monitoring acceptance (NA7.13.2, NRCA-PRC-01-F)
  - Steam trap fault detection acceptance (NA7.19, NRCA-PRC-17-F)
- Major Modifications: None.
- Minor Clarifications: None.

14.5 Acceptance Test Technician Certification Provider (ATTCP)

14.5.1 Provider Qualifications

The requirements to become either a nonresidential lighting controls or mechanical Acceptance Test Technician Certification Provider (ATTCP) are very similar. Therefore, this section will address both the lighting controls and mechanical ATTCP application requirements together, calling out specific differences when warranted. The prospective ATTCP must submit a written application to the CEC that documents the following major elements:

14.5.1.1 Organizational Structure

ATTCPs shall provide written explanations of the organization type, bylaws, and ownership structure. ATTCPs shall explain in writing how their certification program meets the qualification requirements of §10-103.1(c) (or §10-103.2(c)). ATTCPs shall explain in their application to the CEC their organizational structure and their procedures for independent oversight, quality assurance, supervision and support of the acceptance test training, and certification processes (§10-103.1(c)1 and §10-103.2(c)1).

This requirement is necessary to ensure, at a minimum, that the organizations providing certification services to the building industry have a business structure that is conducive to train, certify, and oversee ATTs.

The CEC has approved several ATTCP applicants, and all applications included articles of incorporation, bylaws, and trust agreements. One approved application included the Section 501(c) status (with the corresponding employer identification number) of the organization. A copy of the ethics policy for the ATTCP is recommended.

This section of the application should also include a description of how the organization is conducive to providing training, certification, oversight, and support to the technicians that they will be certifying. The ATTCP may also describe what qualifications and experience the ATTCP may have to operate and oversee an accreditation program.

14.5.1.2 Certification of ATEs

The ATTCPs shall provide written explanations of their certification and oversight of acceptance test employers (ATEs) that employ ATTs. This explanation shall document how the ATTCP ensures that the ATEs are providing quality control and appropriate supervision and support for their ATTs (§10-103.1(c)2 and §10-103.2(c)2).

The ATTCP shall recertify all ATEs before implementing each adopted update to the Energy Code as these updates affect the acceptance test requirements. Recertification requirements and procedures shall only apply to those specific elements that are new or modified in future updates to Energy Code.

ATEs must have an understanding of what tasks the ATT is responsible to complete. Moreover, the ATE must manage and provide support to the ATTs in performing their tasks. The ATTCP is required to describe the training and requirements that they will place on the ATE for these endeavors and issue certificates to qualified ATE applicants. The requirement for the ATEs to be retrained for each new code cycle is intended to maintain the current educational level of the ATEs. The quality control that the ATEs provide to the ATTs is different from the quality control that the ATTCPs provide.

The CEC recognizes that there are many roads to compliance regarding ATE training, certification, and oversight. Technical training typically consists of 4 to 24 hours of instruction. Quality control, supervision, and support requirements implemented by the ATTCP on the ATE can vary considerably. Some elements that the ATTCP might consider implementing, but that are not specifically required by the CEC regulations, include the following:

- The ATTCP may develop a policy to address where a change in employment results in no ATE manager or supervisor having completed the ATE training.
- The ATTCP may adopt an ethics policy for ATEs.

- Union contracting requirements: The ATTCP may be restricted to serving unionized technicians only and as a result the ATTCP may require that the ATE be a party in good standing with a union contract. This may entail several significant requirements for the ATE.
- Third-party certificate holders: The ATTCP may require that the ATE hold a valid certificate from a third party, such as specific types of testing and air balancing (TAB) training.
- Multiple office management requirements: The ATTCP may consider how it will implement ATE training and certification requirements where an ATE has multiple offices. The ATTCP may consider requiring that an ATE with multiple offices shall ensure a middle or senior management level employee at each office has completed the ATE certification training.
- Restrictive employment practices: The ATTCP may restrict the ATE from employing an ATT that is certified by a different ATTCP. Furthermore, the ATTCP may restrict the ATE from holding certificates from multiple ATTCPs.
- Licensing, insurance, and safe practices requirements: The ATTCP may require the ATE to provide initial and ongoing proof of workers' compensation and general liability insurance (typically a minimum dollar amount is specified), local business licenses, injury and illness prevention program, and Code of Safe Practices (typically required to be consistent with the California Code of Regulations, Sections 1509 and 3203).
- Equipment Policy: The ATTCP may require the ATE to agree to requirements for ensuring that the ATE and ATT possess and properly maintain diagnostic equipment.

14.5.1.3 Training and Certification Procedures

These requirements are the most significant of the ATTCP regulations. They encapsulate all the required training, testing, certification, and oversight for the ATTs and ATEs that the ATTCP must provide. These requirements describe the level of experience, education, professionalism, and accountability of the ATT that the CEC is seeking and that the ATTCP must enforce.

ATTCPs shall include with their application a complete copy of all training and testing procedures, manuals, handbooks, and materials. ATTCPs shall explain in writing how their training and certification procedures include, but are not limited to, the following (§10-103.1(c)3 et seq. and §10-103.2(c)3 et seq.):

A. Training Scope

The ATT training must include both classroom and laboratory training. In essence, the ATT must be instructed on all acceptance tests and then practice those instructions in a laboratory setting. Furthermore, the ATT must be educated on the general science regarding acceptance testing, as well as the procedure to complete and submit the correct acceptance test documents.

B. ATT Training

i. **Curricula**.

ATTCP training curricula for lighting controls and mechanical ATTs shall include, but not be limited to, the analysis, theory, and practical application of the items listed in §10-103.1(c)3Bi and §10-103.2(c)3Bi, respectively. These include training on the acceptance tests themselves.

Several approved ATTCPs require extensive classroom training to accomplish this educational requirement. One approved ATTCP requires that each ATT applicant hold a third-party certificate of training that the CEC found to be equivalent to the curricula required.

ii. **Hands-on training**.

The ATTCP shall describe in its application the design and technical specifications of the laboratory boards, equipment, and other elements that will be used to meet the hands-on requirements of the training and certification.

iii. **Prequalification**.

Participation in the certification program shall be limited to persons who have at least three years of professional experience and expertise in either lighting controls and electrical systems or mechanical systems, as determined by the ATTCP.

Professional experience is defined by the ATTCP, but generally means experience in a professional occupation that provides training and work experience related to the systems subject to lighting controls or mechanical acceptance testing. The ATTCP must clarify the process that it will use to determine what experience is considered professional and relevant to either lighting controls or mechanical acceptance testing, as well as to what extent the ATTCP will verify that experience. The following are some relevant questions that the ATTCP should consider when establishing an ATT applicant's prequalified experience, though not specifically required by regulation:

- How is the experience documented (for example, letters from employers or other written evidence), and how is it related to lighting controls or mechanical acceptance testing requirements?
- Should professional experience be demonstrated by requiring applicants to be certified in specifically identified professions, such as:
  - California licensed electrical contractors.
  - California licensed mechanical or HVAC contractors.
  - California certified general electricians.

- California licensed air conditioning repair contractors.
- California licensed professional engineers.
- Lighting control manufacturer representative.
- Certified commissioning professionals.
- Other professional occupations that are demonstrated to provide industry- accepted training and work experience relevant to the systems subject to lighting control or mechanical acceptance testing.

ATTCPs may adopt additional prequalification requirements for ATT applicants. For example, An ATTCP may restrict applicants from participating in the training program if the applicant is decertified by other ATTCPs. Any such additional requirements are at the ATTCP's discretion and not required by the CEC.

iv. **Instructor-to-Trainee Ratio**

The ATTCP shall document in its application to the CEC why its instructor-to-trainee ratio is sufficient to ensure the integrity and efficacy of the curriculum and program based on industry standards and other relevant information.

Typically, the instructor-to-student ratio for classroom training is much higher than for laboratory training. In the applications that the CEC has approved, classroom instructor to student ratios were between 1:25 and 1:35. For laboratory training, the ratios were between 1:6 and 1:12. Most important, each ATTCP application included a discussion of the basis for each ratio.

v. **Tests**

The ATTCP shall describe the written and practical tests used to demonstrate each certification applicant’s competence in all specified subjects. The ATTCPs shall retain all results of these tests for five years from the date of the test.

When developing and implementing both written and practical tests, the ATTCP may consider the following issues:

- Subject matter experts should validate exams by for content.
- Pilot testing and statistical analysis by qualified psychometricians can identify poor quality questions and bias, as well as validating a passing score.
- Checking exam question response option frequency and other measurements of consistency may help validate the exam rigor and justify passing scores and performance standards.

- Exam questions should be evaluated annually to confirm reliability, rigor, and lack of bias.
- Lack of bias should be Validated consistent with the Uniform Guidelines on Employee Selection Procedures (1978) Federal Register, 43(166), 38290-38315.

Measures should be adopted to ensure exam security, such as having multiple versions of exams with random question generation and at least twice the number of questions in a validated question bank than are scored on any given test.

vi. **Recertification.**

The ATTCP shall recertify all ATTs before implementing each adopted update to the Energy Code when these updates affect the acceptance test requirements. Recertification requirements and procedures shall apply only to those specific elements that are new or modified in future updates to the Energy Code.

The ATTCP shall develop recertification training curricula for ATTs consistent with training requirements in §10-103.1(c)3A and §10-103.1(c)3B (or §10-103.2(c)3A and §10-103.2(c)3B) and shall submit the proposed recertification training curricula to the CEC for review and approval in the update report required under §10-103.1(d)2 (or §10-103.2(d)2). Once approved, the ATTCP will implement the recertification process.

C. ATE Training

Training for ATEs shall consist of at least a single class or webinar consisting of at least four hours of instruction that covers the scope and process of the lighting controls or mechanical systems acceptance tests in the Energy Code.

D. Complaint Procedures

The ATTCPs shall describe in their applications to the CEC procedures for accepting and addressing complaints regarding the performance of any ATT or ATE certified by the ATTCP and explain how building departments and the public will be notified of these proceedings.

E. Decertification Procedures

The ATTCPs shall describe in their applications to the CEC procedures for revoking their certification of ATTs and ATEs based upon poor quality or ineffective work, failure to perform acceptance tests, falsification of documents, failure to comply with the documentation requirements of these regulations, or other specified actions that justify decertification. The ATTCP shall also describe its general procedures for decertified ATTs or ATEs seeking to regain their certification status, including eligibility requirements for recertification (if any).

F. Quality Assurance and Accountability

The quality assurance and accountability requirements for lighting controls and mechanical ATTCPs vary significantly for the 2022 Energy Code, so they will be discussed separately.

- Lighting Controls

  The ATTCP shall describe in its application to the CEC its procedures for conducting quality assurance and accountability activities, including, but not limited to, the following:

  - The ATTCP shall include quality assurance and accountability measures, including, but not limited to, independent oversight of the certification materials, processes, and procedures; visits to building sites where certified technicians are completing acceptance tests; certification process evaluations; building department surveys to determine acceptance testing effectiveness; and expert review of the training curricula developed for Energy Code §130.4 and §160.5(e).
  - The ATTCP shall review a random sample of no fewer than 1 percent of each ATT’s completed compliance forms and shall perform randomly selected on-site audits of no fewer than 1 percent of each ATT’s completed acceptance tests. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard.

  The consequences of failed audits should be fully described by the ATTCP. ATTCPs might consider whether to require a higher percentage of document and on-site audits the first few years of operation to ensure that any initial issues with training or compliance are identified and addressed.

  For example, one ATTCP proposed the following:

  - For the first three years of operation, review a random sample of 6 percent of each technician's completed documents and perform on-site audits of 6 percent of acceptance tests.
  - For years 4 and 5 of the ATTCP operation, review a random sample of 4 percent of each technician's completed documents and perform on-site audits of 4 percent of acceptance tests.
  - After five years of operation, reduce a random sample of 2 percent of each ATT's completed compliance documents and perform on-site audits of 2 percent of acceptance tests.

- Mechanical Systems

The ATTCP shall describe in its applications to the CEC procedures for conducting quality assurance and accountability activities, including, but not limited to, the following:

- The ATTCPs shall include quality assurance and accountability measures, including, but not limited to, independent oversight of the certification materials, processes, and procedures; visits to building sites where ATTs are completing acceptance tests; certification process evaluations; building department surveys to determine acceptance testing effectiveness; and expert review of the training curricula developed for Energy Code §120.5 and §160.3(d).
- The ATTCP shall review a random sample of no fewer than 1 percent of each ATT's completed compliance forms. The ATTCP shall also randomly select and shadow audit no fewer than 1 percent of each ATE's overseen projects, following the assigned ATT and observing his or her performance on the job site. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard.

The mechanical regulation generally follows the same requirements as lighting controls, except the focus for on-site audits is on the ATEs rather than the ATTs.

G. Certification Identification Number and Verification of ATT and ATE Certification Status

The ATTCP shall describe in its applications to the CEC procedures for recording, tracking, and communicating certification status, including but not limited to the following:

- Upon certification of an ATT or ATE, the ATTCP shall issue a unique certification identification number to the ATT or ATE.
- The ATTCP shall maintain an accurate public record of the certification status for all ATTs and ATEs that the ATTCP has certified, including any ATTs or ATEs who have been decertified as specified in §10-103.1(c)3E or §10-103.2(c)3E.
- The ATTCP shall provide verification of current ATT certification status upon request to authorized document registration provider personnel or enforcement agency personnel to determine the ATT's eligibility to sign certificate of acceptance documentation.

Energy Code compliance will also be simplified by requiring the ATT to include its assigned certification number on the compliance documentation, thereby allowing the enforcement agency and the CEC to track the effectiveness of this certification program.

The ATTCP is not required to implement an on-line presence of any kind for compliance with these regulations. However, the applications that the CEC has approved all include the implementation of an online presence to contend with the ATT/ATE application processing, complaints process, certification status, and ATT/ATE contact information.

H. Electronic Database System

The ATTCP shall maintain, or by suitable contractual requirements cause to be maintained, an electronic database system approved by the CEC. The electronic database system shall be capable of all the following:

i. Support all activities for the ATTCP to comply with its quality assurance program as required by §10-103.1(c)3F.

ii. For no less than five years, record and preserve all certificates of acceptance offered for certification by the ATTCP and as performed by its own certified ATTs.

iii. Allow the transmission of electronic copies of each completed certificate of acceptance to the ATT that performed the test, the ATE associated with that ATT, or both.

   a. Each page of each certificate of acceptance shall bear the logo of the ATTCP or other identifying insignia as approved by the CEC.

   b. The electronic copy shall be capable of being printed.

   c. The ATTCP may apply to the CEC for approval to use alternative compliance documents that differ from those approved for use by the CEC but must demonstrate that these alternative compliance documents do not differ in format, informational order, or content from approved compliance documents.

iv. Provide a means of verifying any certificate of acceptance to the enforcement agency having jurisdiction as identified on the certificate of acceptance.

v. Provide the CEC with any of the following project data or documents upon request: project address, permit numbers, ATT and ATE certification numbers, certificates of acceptance, compliance forms, installation forms, and record of quality assurance review. The CEC may adopt an Application Programming Interface (API) for providing data electronically. Within one year of development of an API, the ATTCP's electronic database system shall have the ability to transfer project data to the CEC through the API upon completion of the project or at established intervals no longer than monthly.

I. Compliance Document Recording and Repository Reporting Requirement

i. The ATTCP shall record all certificates of compliance (§10-103(a)1), certificates of installation (§10-103(a)3), and certificates of acceptance (§10-103(a)4) associated with any acceptance test specified in Part 6, §130.4, §160.5(e), §120.5, and 160.3(d).

ii. Contingent upon CEC approval of the threshold (§10-103.1(b)) or §10-103.2(b)) and upon availability and approval of an electronic document repository by the Executive Director, the ATTCP shall submit monthly data transfer packets to the CEC to an electronic document repository for retention consistent with CEC instructions.

14.5.2 Requirements for ATTCPs to Provide Regular Reports

§10-103.1(d) and §10-103.2(d) require ATTCPs to submit two periodic reports to the CEC. All required reports shall contain a signed certification that the ATTCP has met all requirements for this program.

These reporting requirements are intended to ensure that the CEC has a reasonable level of control on the ATTCP without being unnecessarily involved in the day-to-day operations of the ATTCP.

14.5.2.1 Annual Report

The ATTCP shall provide an annual report to the CEC that includes:

1. A summary of the certification services provided over the reporting period, including the total number of ATTs and ATEs certified by the ATTCP during the reporting period and to date.
2. A summary of all actions taken against any ATT or ATE as a result of the complaint or quality assurance procedures described by the ATTCP as required under §10-103.1(c)3D and §10-103.1(c)3F (or §10-103.2(c)3D and §10-103.2(c)3F).
3. A summary of the quality assurance and accountability activities conducted over the reporting period, including the compliance forms reviewed and the on-site audits performed as required under §10-103.1(c)3F(ii) (or §10-103.2(c)3F(ii)) during the reporting period and to date.
4. A summary of the number and type of acceptance tests performed in each local jurisdiction over the reporting period and to date.
5. A signed certification to the CEC that the ATTCP continues to meet the requirements of §10-103.1 (or §10-103.2).

The annual report can include adjustments that are proposed, however, these proposals must be approved according to the application amendment process in §10-103.1(f) or §10-103.2(f).

14.5.2.2 Update Report

The ATTCP shall have no less than six months following the adoption of an update to the Energy Code to prepare an update report. The ATTCP shall submit an update report to the CEC not less than six months before the effective date of any newly adopted update to the Energy Code. The ATTCP shall report to the CEC what application amendments are proposed to address changes to the Energy Code or to ensure training reflects the variety of lighting controls (or mechanical systems) that are encountered in the field.

All required update reports shall contain a signed certification that the ATTCP continues to meet the requirements §10-103.1 (or §10-103.2). Update reports shall be approved through the amendment process provided under §10-103.1(f) (or §10-103.2(f)).

14.5.3 Amendment of ATTCP Applications

The ATTCP may amend a submitted or approved application as described in §10-103.1(f) and §10-103.2(f). The amendment process is intended to give the ATTCP an opportunity both during its initial application approval process and post approval to modify its application or operations. This is so that ATTCPs can operate as openly as possible with the CEC and address issues as they arise.

The amendment process depends on whether changes being made to an ATTCP application are substantive or non-substantive. Substantive amendments will require an approval from the CEC at a regular business meeting. Non-substantive amendments can be approved by the Executive Director. The requirements and approval process for both types of amendments are discussed in detail below.

14.5.3.1 Amendment Scope

A. Non-substantive Changes

A non-substantive change is a change that does not substantively alter the requirements of the application materials for the ATTCP, ATT, or ATE. For amendments making only non-substantive changes, the ATTCP shall submit:

- A letter describing the change to the CEC as an addendum to the application.
- A replacement copy of the affected sections of the ATTCP application with the changes incorporated.
- A copy of the affected sections of the ATTCP application showing the changes in underline and strikeout format.

B. Substantive Changes

A substantive change is a change that substantively alters the requirements of the application materials for the ATTCP, ATT, or ATE. For amendments making any substantive changes, the ATTCP shall submit the following:

- A document describing the scope of the change to the application, the reason for the change and the potential impact to the ATTCP, ATT, and ATE as an addendum to the application;
- A replacement copy of the affected sections of the ATTCP application with the changes incorporated; and
- A copy of the affected sections of the ATTCP application showing the changes in underline and strikeout format.

14.5.3.2 Amendment Review

Amendments submitted prior to approval of an ATTCP application shall be included in the application's application review and determination process specified in §10-103.1(e) or §10-103.2(e).

Amendments submitted after approval of an ATTCP's application that contain only non-substantive changes shall be reviewed by the Executive Director for consistency with §10-103.1 or §10-103.2. Amendments determined to be consistent with this section shall be incorporated into the approval as errata.

Amendments submitted after approval of an ATTCP's application that contain any substantive changes shall be subject to the application review and determination process specified in §10-103.1(e) or §10-103.2(e). If the CEC finds that the amended application does not meet the requirements of §10-103.1 or §10-103.2, then the ATTCP shall either abide by the terms of their previously approved application or have its approval suspended.

NOTE: For Documents and User Instructions, please visit our website at: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency

Table 1 NRCC Forms

Type	Abbreviation	Category	Document Description
NRCC	LTI	Lighting	Indoor Lighting
NRCC	LTO	Lighting	Outdoor Lighting
NRCC	LTS	Lighting	Sign Lighting
NRCC	ENV	Envelope	Envelope
NRCC	SAB	Solar and Battery	Solar and Battery
NRCC	ELC	Electrical	Electrical
NRCC	PLB	Plumbing	Plumbing
NRCC	MCH	Mechanical	Mechanical
NRCC	PRC	Process	Covered Process
NRCC	CXR	Commissioning	Commissioning
NRCC	PRF		Performance

Table 2 NRCI Forms

Type	Abbreviation	Category	Document Description
NRCI	LTI	Lighting	Indoor Lighting
NRCI	LTO	Lighting	Outdoor Lighting
NRCI	LTS	Lighting	Sign Lighting
NRCI	ENV	Envelope	Envelope
NRCI	SRA	Solar Access Requirements	Solar Access Requirements
NRCI	ELC	Electrical	Electrical
NRCI	PLB	Plumbing	Plumbing
NRCI	MCH	Mechanical	Mechanical
NRCI	PRC	Process	Process

Table 3 NRCA Forms

Type	Abbreviation	Category	Document Description
NRCA	NRCA-ENV-02	ENVELOPE	Fenestration Acceptance
NRCA	NRCA-ENV-03F	ENVELOPE	Daylighting Design PAFs
NRCA	NRCA-LTI-02	LIGHTING	Shut Off Lighting Control
NRCA	NRCA-LTI-03	LIGHTING	Automatic Daylighting Control
NRCA	NRCA-LTI-04	LIGHTING	Demand Response Controls
NRCA	NRCA-LTI-05	LIGHTING	Institutional Tuning PAF
NRCA	NRCA-LTO-02	LIGHTING	Outdoor Lighting Controls
NRCA	NRCA-MCH-02	MECHANICAL	Outdoor Air
NRCA	NRCA-MCH-03	MECHANICAL	Constant Volume Single Zone HVAC
NRCA	NRCA-MCH-04a	MECHANICAL	Duct Leakage
NRCA	NRCA-MCH-04b	MECHANICAL	Duct Leakage
NRCA	NRCA-MCH-05	MECHANICAL	Economizer DOAS HRV ERV
NRCA	NRCA-MCH-06	MECHANICAL	Demand Control Ventilation
NRCA	NRCA-MCH-07	MECHANICAL	Supply Fan Variable Controls Acceptance
NRCA	NRCA-MCH-08	MECHANICAL	Valve Leakage Test
NRCA	NRCA-MCH-09	MECHANICAL	Water Temp Reset
NRCA	NRCA-MCH-10	MECHANICAL	Hydronic System Variable Flow Control Acceptance
NRCA	NRCA-MCH-11	MECHANICAL	Automatic Demand Shed Controls
NRCA	NRCA-MCH-12	MECHANICAL	Packaged Units
NRCA	NRCA-MCH-13	MECHANICAL	FDD for AHU and Zone Terminals
NRCA	NRCA-MCH-14	MECHANICAL	Distributed Energy Storage DX AX Systems
NRCA	NRCA-MCH-15	MECHANICAL	Thermal Energy Storage
NRCA	NRCA-MCH-16	MECHANICAL	Supply Air Temperature Reset Controls
NRCA	NRCA-MCH-17	MECHANICAL	Condenser Water Temperature Reset Controls
NRCA	NRCA-MCH-18	MECHANICAL	EMS System Acceptance
NRCA	NRCA-MCH-19	MECHANICAL	Occupied Standby
NRCA	NRCA-MCH-20a	MECHANICAL	MF Dwelling Inspection Acceptance
NRCA	NRCA-MCH-20b	MECHANICAL	MF Dwelling Kitchen Exhaust
NRCA	NRCA-MCH-20c	MECHANICAL	MF IAQ Ventilation System
NRCA	NRCA-MCH-20d	MECHANICAL	MF Dwelling HRV-ERV
NRCA	NRCA-MCH-21	MECHANICAL	Multifamily Leakage
NRCA	NRCA-MCH-22	MECHANICAL	System Duct Leakage
NRCA	NRCA-MCH-23	MECHANICAL	HRV ERV Verification
NRCA	NRCA-PRC-01	PROCESS	Compressed Air System Controls
NRCA	NRCA-PRC-02	PROCESS	Kitchen Exhaust SC
NRCA	NRCA-PRC-03	PROCESS	Parking Garage Ventilation

Type	Abbreviation	Category	Document Description
NRCA	NRCA-PRC-04	PROCESS	Refrigerated Warehouse Evap & Fan Ctrl
NRCA	NRCA-PRC-05	PROCESS	Evaporative Condenser Controls
NRCA	NRCA-PRC-06	PROCESS	Air Cooled Condensers
NRCA	NRCA-PRC-07	PROCESS	Variable Speed Compressors
NRCA	NRCA-PRC-08	PROCESS	Refrigerated Warehouse Underslab Heating
NRCA	NRCA-PRC-12	PROCESS	Elevator Light & Vent Ctrl
NRCA	NRCA-PRC-13	PROCESS	Escalator and Moving Walkways Speed Control
NRCA	NRCA-PRC-14	PROCESS	Lab Exhaust Ventilation System
NRCA	NRCA-PRC-15	PROCESS	Fume Hood
NRCA	NRCA-PRC-16	PROCESS	Adiabatic Condenser

Table 4 NCRV Forms

Type	Abbreviation	Category	Document Description
NRCV	NRCV-MCH-04a	Mechanical	Duct Leakage Test New Construction
NRCV	NRCV-MCH-04c	Mechanical	Duct Leakage LLAHU
NRCV	NRCV-MCH-04d	Mechanical	Duct Leakage Test Existing Construction
NRCV	NRCV-MCH-04e	Mechanical	Duct Leakage Test Sealing Accessible Leaks
NRCV	NRCV-MCH-24a	Mechanical	Enclosure Air Leakage Worksheet Single Point Test Manual Meter
NRCV	NRCV-MCH-24b	Mechanical	Enclosure Air Leakage Worksheet Single Point Test Automatic Meter
NRCV	NRCV-MCH-27b	Mechanical	Highrise Residential
NRCV	NRCV-MCH-27c	Mechanical	Highrise Residential Scheduled Real Time Control
NRCV	NRCV-MCH-32	Mechanical	Local Mechanical Exhaust
NRCV	NRCV-PLB-21	Plumbing	Multifamily Central Hot Water System Distribution
NRCV	NRCV-PLB-22	Plumbing	Individual Dwelling Unit Hot Water System Distribution

Table 5 LMCI Forms

Type	Abbreviation	Category	Document Description
LMCI	LMCI-ELC-01-E	ELECTRICAL	Electric Ready
LMCI	LMCI-ENV-21-H	ENVELOPE	QII Framing Stage
LMCI	LMCI-ENV-22-H	ENVELOPE	QII Insulation Stage
LMCI	LMCI-MCH-01a	MECHANICAL	Space Conditioning System-Performance

Type	Abbreviation	Category	Document Description
LMCI	LMCI-MCH-01b	MECHANICAL	Space Conditioning System-Prescriptive Alterations
LMCI	LMCI-MCH-01c	MECHANICAL	Space Conditioning System-Prescriptive NCB
LMCI	LMCI-MCH-01d	MECHANICAL	Space Conditioning System-Performance-E+A+A
LMCI	LMCI-MCH-20a	MECHANICAL	Duct Leakage Test-New Construction
LMCI	LMCI-MCH-20b	MECHANICAL	Duct Leakage LLDCS
LMCI	LMCI-MCH-20c	MECHANICAL	Duct Leakage LLAHU
LMCI	LMCI-MCH-20d	MECHANICAL	Duct Leakage Test-Existing Construction
LMCI	LMCI-MCH-20e	MECHANICAL	Duct Leakage Test Sealing Accessible Leaks
LMCI	LMCI-MCH-21-H	MECHANICAL	Duct Location
LMCI	LMCI-MCH-22a	MECHANICAL	Fan Efficacy All Zones Calling Only
LMCI	LMCI-MCH-22b	MECHANICAL	Fan Efficacy Every Zonal Control Mode
LMCI	LMCI-MCH-22c	MECHANICAL	Fan Efficacy All Zones Calling Only With CFVCS
LMCI	LMCI-MCH-22d	MECHANICAL	Fan Efficacy Every Zonal Control Mode With CFVCS
LMCI	LMCI-MCH-23a	MECHANICAL	Airflow Rate All Zones Calling Only
LMCI	LMCI-MCH-23b	MECHANICAL	Airflow Rate Every Zonal Control Mode
LMCI	LMCI-MCH-23c	MECHANICAL	Airflow Rate Best Settings
LMCI	LMCI-MCH-23d	MECHANICAL	Airflow Rate Measurement Only All Zones Calling Only
LMCI	LMCI-MCH-23e	MECHANICAL	Airflow Rate All Zones Calling Only With CFVCS
LMCI	LMCI-MCH-23f	MECHANICAL	Airflow Rate Every Zonal Control Mode With CFVCS
LMCI	LMCI-MCH-24a	MECHANICAL	Enclosure Air Leakage Worksheet Single Point Test Manual Meter
LMCI	LMCI-MCH-24b	MECHANICAL	Enclosure Air Leakage Worksheet Single Point Test Automatic Meter
LMCI	LMCI-MCH-25a	MECHANICAL	Refrigerant Charge Superheat
LMCI	LMCI-MCH-25b	MECHANICAL	Refrigerant Charge Subcooling
LMCI	LMCI-MCH-25c	MECHANICAL	Refrigerant Charge Weigh In
LMCI	LMCI-MCH-25e	MECHANICAL	Refrigerant Charge Winter Setup
LMCI	LMCI-MCH-25f	MECHANICAL	Refrigerant Charge Packaged System Manufacturer Certification
LMCI	LMCI-MCH-26-H	MECHANICAL	Rated System Verification
LMCI	LMCI-MCH-27b	MECHANICAL	Continuous Mech Vent Total Vent Rate Method
LMCI	LMCI-MCH-28-H	MECHANICAL	Return Duct And Filter Grille Design-Table 150

Type	Abbreviation	Category	Document Description
LMCI	LMCI-MCH-29-H	MECHANICAL	Supply Duct Surface Area Buried Ducts
LMCI	LMCI-MCH-32-L	MECHANICAL	Local Mechanical Exhaust
LMCI	LMCI-MCH-33-H	MECHANICAL	VCHP Compliance Credit
LMCI	LMCI-PLB-01-E	PLUMBING	Non HERS Multifamily Central Hot Water System Distribution
LMCI	LMCI-PLB-02-E	PLUMBING	Non HERS Individual Dwelling Unit Hot Water System Distribution
LMCI	LMCI-PLB-21-H	PLUMBING	Multifamily Central Hot Water System Distribution
LMCI	LMCI-PLB-22-H	PLUMBING	Individual Dwelling Unit Hot Water System Distribution

Table 6 LMVI Forms

Type	Abbreviation	Category	Document Description
LMCV	LMCV-ENV-21-H	ENVELOPE	HERS QII Framing Stage
LMCV	LMCV-ENV-22-H	ENVELOPE	HERS QII Insulation Stage
LMCV	LMCV-MCH-20a-	MECHANICAL	Duct Leakage Test New Construction
LMCV	LMCV-MCH-20b-	MECHANICAL	Duct Leakage-LLDCS
LMCV	LMCV-MCH-20c-	MECHANICAL	Duct Leakage-LLAHU
LMCV	LMCV-MCH-20d-	MECHANICAL	Duct Leakage Test-Existing Construction
LMCV	LMCV-MCH-20e-	MECHANICAL	Duct leakage Test Sealing Accessible Leaks
LMCV	LMCV-MCH-21-D	MECHANICAL	Duct Location
LMCV	LMCV-MCH-22a-	MECHANICAL	Fan Efficacy All Zones Calling Only
LMCV	LMCV-MCH-22b-	MECHANICAL	Fan Efficacy Every Zonal Control Mode
LMCV	LMCV-MCH-22c-	MECHANICAL	Fan Efficacy All Zones Calling Only With CFVCS
LMCV	LMCV-MCH-22d-	MECHANICAL	Fan Efficacy Every Zonal Control Mode-With CFVCS
LMCV	LMCV-MCH-23a-	MECHANICAL	Airflow Rate All Zones Calling Only
LMCV	LMCV-MCH-23b-	MECHANICAL	Airflow Rate Every Zonal Control Mode
LMCV	LMCV-MCH-23c-	MECHANICAL	Airflow Rate Best
LMCV	LMCV-MCH-23d-	MECHANICAL	Airflow Rate Measurement Only All Zones Calling Only
LMCV	LMCV-MCH-23e-	MECHANICAL	Airflow Rate All Zones Calling Only With CFVCS
LMCV	LMCV-MCH-23f-	MECHANICAL	Airflow Rate-Every Zonal Control Mode-With CFVCS
LMCV	LMCV-MCH-24a-	MECHANICAL	Enclosure Air Leakage Worksheet-Single Point Test-Manual Meter

Type	Abbreviation	Category	Document Description
LMCV	LMCV-MCH-24b-	MECHANICAL	Enclosure Air Leakage Worksheet-Single Point Test-Automatic Meter
LMCV	LMCV-MCH-25a-	MECHANICAL	Refrigerant Charge-Superheat
LMCV	LMCV-MCH-25b-	MECHANICAL	Refrigerant Charge-Subcooling
LMCV	LMCV-MCH-25c-	MECHANICAL	Refrigerant Charge-Weigh in Observation
LMCV	LMCV-MCH-25d-	MECHANICAL	Refrigerant Charge-FID
LMCV	LMCV-MCH-25e-	MECHANICAL	Refrigerant Charge- Winter Set Up
LMCV	LMCV-MCH-26-R	MECHANICAL	Rated System Verification
LMCV	LMCV-MCH-27b-	MECHANICAL	Continuous Mech Vent-Fan Vent Rate Method
LMCV	LMCV-MCH-28-R	MECHANICAL	Return Duct And Filter Grille Design-Table 150
LMCV	LMCV-MCH-29-S	MECHANICAL	Supply Duct Surface Area Buried Ducts
LMCV	LMCV-MCH-32-L	MECHANICAL	Local Mechanical Exhaust
LMCV	LMCV-MCH-33-V	MECHANICAL	VCHP Compliance Credit
LMCV	LMCV-PLB-21-H	PLUMBING	HERS-Multifamily Central Hot Water System Distribution
LMCV	LMCV-PLB-22-H	PLUMBING	HERS-Individual Dwelling Unit Hot Water System Distribution

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Appendix B Excerpts from the Appliance Efficiency Regulations

TABLE T-1
NORMAL IMPEDANCE RANGES FOR LIQUID-IMMERSED TRANSFORMERS

Single-phase		*Three-phase*	
kVA	***Impedance (%)***	***kVA***	***Impedance (%)***
10	1.0–4.5	15	1.0–4.5
15	1.0–4.5	30	1.0–4.5
25	1.0–4.5	45	1.0–4.5
37.5	1.0–4.5	75	1.0–5.0
50	1.5–4.5	112.5	1.2–6.0
75	1.5–4.5	150	1.2–6.0
100	1.5–4.5	225	1.2–6.0
167	1.5–4.5	300	1.2–6.0
250	1.5–6.0	500	1.5–7.0
333	1.5–6.0	750	5.0–7.5
500	1.5–7.0	1000	5.0–7.5
667	5.0–7.5	1500	5.0–7.5
833	5.0–7.5	2000	5.0–7.5
		2500	5.0–7.5

TABLE T-2
NORMAL IMPEDANCE RANGES FOR DRY-TYPE TRANSFORMERS

Single-phase		*Three-phase*	
kVA	***Impedance (%)***	***kVA***	***Impedance (%)***
15	1.5–6.0	15	1.5–6.0
25	1.5–6.0	30	1.5–6.0
37.5	1.5–6.0	45	1.5–6.0
50	1.5–6.0	75	1.5–6.0
75	2.0–7.0	112.5	1.5–6.0
100	2.0–7.0	150	1.5–6.0
167	2.5–8.0	225	3.0–7.0
250	3.5–8.0	300	3.0–7.0
333	3.5–8.0	500	4.5–8.0
500	3.5–8.0	750	5.0–8.0
667	5.0–8.0	1000	5.0–8.0
833	5.0–8.0	1500	5.0–8.0
		2000	5.0–8.0
		2500	5.0–8.0

TABLE A-1
NON-COMMERCIAL REFRIGERATOR, REFRIGERATOR-FREEZER, AND FREEZER TEST METHODS

Appliance	*Test Method*
Non-commercial refrigerators, designed for the refrigerated storage of food at temperatures above 32°F and below 39°F, configured for general refrigerated food storage; refrigerator-freezers; and freezers.	10 C.F.R. sections 430.23(a) (Appendix A1 to Subpart B of part 430) and 430.23(b) (Appendix B1 to Subpart B of part 430), as applicable for models manufactured before September 15, 2014 10 C.F.R. sections 430.23(a) (Appendix A to Subpart B of part 430) and 430.23(b) (Appendix B to Subpart B of part 430), as applicable for models manufactured on or after September 15, 2014
Wine chillers that are consumer products	10 C.F.R. section 430.23(a) (Appendix A1 to Subpart B of part 430), with the following modifications: Standardized temperature as referred to in Section 3.2 of Appendix A1 shall be 55°F (12.8°C). The calculation of test cycle energy expended (ET) in section 5.2.1.1 of Appendix A1 shall be made using the modified formula: ET=(EP x 1440 x k)/T Where k = 0.85

TABLE A-2
COMMERCIAL REFRIGERATORS, REFRIGERATOR-FREEZER, AND FREEZER TEST METHODS

Appliance	*Test Method*
Automatic commercial ice makers	10 C.F.R. sections 431.133 and 431.134
Refrigerated bottled or canned beverage vending machines	10 C.F.R. sections 431.293 and 431.294
Refrigerated buffet and preparation tables	ANSI/ASTM F2143-01
Other commercial refrigerators, refrigerator-freezers, and freezers, with doors	10 C.F.R. sections 431.63 and 431.64
Other commercial refrigerators, refrigerator-freezers, and freezers, without doors	10 C.F.R. sections 431.63 and 431.64
Walk-in coolers and walk-in freezers	10 C.F.R. sections 431.303 and 431.304

TABLE B-1
ROOM AIR CONDITIONER, ROOM AIR-CONDITIONING HEAT PUMP, PACKAGED TERMINAL AIR CONDITIONER, AND PACKAGED TERMINAL HEAT PUMP TEST METHODS

Appliance	*Test Method*
Room air conditioners and room air-conditioning heat pumps	10 C.F.R. section 430.23(f) (Appendix F to Subpart B of part 430)
Packaged terminal air conditioners and packaged terminal heat pumps	10 C.F.R. sections 431.95 and 431.96

TABLE C-1
CENTRAL AIR CONDITIONER TEST METHODS

Appliance	*Test Method*
Computer Room Air Conditioners	ANSI/ASHRAE 127-2001
evaporatively-cooled	10 C.F.R. sections 431.95 and 431.96
air-cooled, glycol-cooled, water-cooled	
Other electric-powered unitary air-conditioners and electric-powered heat pumps	10 C.F.R. section 430.23(m) (Appendix M to Subpart B of part 430)
air-cooled air conditioners and air-source heat pumps	10 C.F.R. sections 431.95 and 431.96
< 65,000 Btu/hr, single-phase	10 C.F.R. sections 431.95 and 431.96
< 65,000 Btu/hr, three-phase	10 C.F.R. sections 431.95 and 431.96
≥ 65,000 and < 760,000 Btu/hr	
evaporatively-cooled air conditioners < 240,000 Btu/hr	10 C.F.R. sections 431.95 and 431.96
water-cooled air conditioners and water-source heat pumps	ARI/ISO-13256-1:1998
< 240,000 Btu/hr	ARI/ISO-13256-1:1998
ground water-source heat pumps	
ground-source closed-loop heat pumps	
Variable Refrigerant Flow Multi-Split Systems	10 C.F.R. sections 431.95 and 431.96
Single Package Vertical Air Conditioners and Single Package Vertical Heat Pumps	10 C.F.R. sections 431.95 and 431.96
Gas-fired air conditioners and gas-fired heat pumps	ANSI Z21.40.4-1996 as modified by CEC, Efficiency Calculation Method for Gas-Fired Heat Pumps as a New Compliance Option (1996)

TABLE D-1
SPOT AIR CONDITIONER, CEILING FAN, CEILING FAN LIGHT KIT, EVAPORATIVE COOLER, WHOLE HOUSE FAN, RESIDENTIAL EXHAUST FAN, AND DEHUMIDIFIER TEST METHODS

Appliance	*Test Method*
Spot Air Conditioners	ANSI/ASHRAE 128-2001
Ceiling Fans, Except Low-Profile Ceiling Fans	10 C.F.R. section 430.23(w) (Appendix U to Subpart B of part 430)
Ceiling Fan Light Kits	10 C.F.R. section 430.23(x) (Appendix V to Subpart B of part 430)
Evaporative Coolers	ANSI/ASHRAE 133-2008 for packaged direct evaporative coolers and packaged indirect/direct evaporative coolers; ANSI/ASHRAE 143-2007 for packaged indirect evaporative coolers
Whole House Fans	HVI-916, tested with manufacturer-provided louvers in place (2009)
Dehumidifiers	10 C.F.R. section 430.23(z) (Appendix X to Subpart B of part 430) OR 10 C.F.R. section 430.23(z) (Appendix X1 to Subpart B of part 430) (at manufacturer's discretion) for models manufactured before April 29, 2013 10 C.F.R. section 430.23(z) (Appendix X1 to Subpart B of part 430) for models manufactured on or after April 29, 2013
Residential Exhaust Fans	HVI-916 (2009)

TABLE E-1
GAS AND OIL SPACE HEATER TEST METHODS

Appliance	***Test Method***
Central furnaces < 225,000 Btu/hr, single phase < 225,000 Btu/hr, three phase ≥ 225,000 Btu/hr	10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430) 10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430) or 10 C.F.R. sections 431.75 and 431.76 (at manufacturer's option) 10 C.F.R. sections 431.75 and 431.76
Gas infrared heaters patio heaters gas-fired high-intensity infrared heaters gas-fired low-intensity infrared heaters	ASTM F2644-07 ANSI Z83.19- 001 ANSI Z83.20-
Unit heaters gas- fired oil-fired	ANSI Z83.8-2002* UL 731-1995*
Gas duct furnaces	ANSI Z83.8-
Boilers < 300,000 Btu/hr ≥ 300,000 Btu/hr	10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430) 10 C.F.R. sections 431.85 and 431.86
Wall furnaces, floor furnaces, and room heaters	10 C.F.R. section 430.23(o) (Appendix O to Subpart B of part 430)
*To calculate maximum energy consumption during standby, measure the gas energy used in one hour (in Btus) and the electrical energy used (in watt-hours) over a one-hour period, when the main burner is off. Divide Btus and watt-hours by one hour to obtain Btus per hour and watts. Divide Btus per hour by 3.412 to obtain watts. Add watts of gas energy to watts of electrical energy to obtain standby energy consumption in watts.	

TABLE F-1
SMALL WATER HEATER TEST METHODS

Appliance	*Test Method*
Small water heaters that are federally regulated consumer products	10 CFR Section 430.23(e) (Appendix E to Subpart B of Part 430) (2008)
Small water heaters that are not federally regulated consumer products	
Gas and oil storage-type < 20 gallons rated capacity	ANSI/ASHRAE 118.2-1993
Booster water heaters	ANSI/ASTM F2022-00 (for all matters other than volume) ANSI Z21.10.3-1998 (for volume)
Hot water dispensers	Test Method in 1604(f)(4)
Mini-tank electric water heaters	Test Method in 1604(f)(5)
All others	10 CFR Section 430.23(e) (Appendix E to Subpart B of Part 430) (2008)

TABLE F-2
STANDARDS FOR LARGE WATER HEATERS EFFECTIVE OCTOBER 29, 2003

Appliance	*Input to Volume Ratio*	*Size (Volume)*	*Minimum Thermal Efficiency (%)*	*Maximum Standby Loss*[1,2]
Gas storage water heaters	< 4,000 Btu/hr/gal	Any	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Gas instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Gas hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil storage water heaters	< 4,000 Btu/hr/gal	Any	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Electric storage water heaters	< 4,000 Btu/hr/gal	Any	–	$0.3 + 27/V_m$ %/hr

[1] Standby loss is based on a 70°F temperature difference between stored water and ambient requirements. In the standby loss equations, Vr is the rated volume in gallons, Vm is the measured volume in gallons, and Q is the nameplate input rate in Btu/hr.

[2] Water heaters and hot water supply boilers having more than 140 gallons of storage capacity are not required to meet the standby loss requirement if the tank surface is thermally insulated to R- 12.5, if a standing pilot light is not installed, and for gas- or oil-fired storage water heaters, there is a flue damper or fan-assisted combustion.

TABLE G-1
POOL HEATER TEST METHODS

Appliance	*Test Method*
Gas-fired and oil-fired pool heaters	10 C.F.R. section 430.23(p) (Appendix P to Subpart B of part 430)
Electric resistance pool heaters	ANSI/ASHRAE 146-1998
Heat pump pool heaters	ANSI/ASHRAE 146-1998, as modified by Addendum Test Procedure published by Pool Heat Pump Manufacturers Association dated April 1999, Rev 4: Feb. 28, 2000:

Reading	*Standard Temperature Rating*	*Low-Temperature Rating*	*Spa Conditions Rating*
Air Temperature Dry bulb Wet bulb	 27.0°C (80.6°F) 21.7°C (71.0°F)	 10.0°C (50.0°F) 6.9°C (44.4°F)	 27.0°C (80.6°F) 21.7°C (71.0°F)
Relative Humidity	63%	63%	63%
Pool Water Temperature	26.7°C (80.0°F)	26.7°C (80.0°F)	40.0°C (104.0°F)

TABLE R-1
COOKING PRODUCT AND FOOD SERVICE EQUIPMENT TEST METHODS

Appliance	*Test Method*
Cooking products that are consumer products	10 CFR Section 430.23(i) (Appendix I to Subpart B of Part 430) (2008)
Commercial hot food holding cabinets	ANSI/ASTM F2140-01 (Test for idle energy rate-dry test) and US EPA's Energy Star Guidelines, "Measuring Interior Volume" (Test for interior volume)
Commercial convection ovens	ANSI/ASTM F1496-99 (Test for energy input rate and idle energy consumption only)
Commercial range tops	ANSI/ASTM F1521-96 (Test for cooking energy efficiency only)

TABLE A-3 STANDARDS FOR NON-COMMERCIAL REFRIGERATORS, REFRIGERATOR-FREEZERS, AND FREEZERS

Appliance	*Defrost*	*Compact, Built- in, Neither*	*Ice*		*Maximum Energy Consumption (kWh/year)*	
			Equipped with Automatic Ice Maker?	*Dispense Ice Through Door?*	*July 1, 2001*[1]	*Sept. 15, 2014*[2]
Refrigerators						
Not 'all refrigerator'	Manual	Neither	--	--	8.82AV + 248.4	7.99AV + 225.0
Not 'all refrigerator'	Manual	Compact	--	--	10.70AV + 299.0	9.03AV + 252.3
'All refrigerator'	Manual	Compact	--	--	10.70AV + 299.0	7.84AV + 219.1
'All refrigerator'	Manual	Neither	--	--	--	6.79AV + 193.6
'All refrigerator'	Automatic	Neither	--	--	9.80AV + 276.0	7.07AV + 201.6
'All refrigerator'	Automatic	Built-in	--	--	--	8.02AV + 228.5
'All refrigerator'	Automatic	Compact	--	--	12.70AV + 355.0	9.17AV + 259.3
Refrigerator-freezers	Manual	Neither	--	--	8.82AV + 248.4	7.99AV + 225.0
	Partial	Neither	--	--	8.82AV + 248.4	7.99AV + 225.0
	Manual	Compact	--	--	--	9.03AV + 252.3
	Partial	Compact	--	--	7.00AV + 398.0	5.91AV + 335.8
Refrigerator-freezers Bottom-Freezer	Automatic	Neither	No	--	4.60AV + 459.0	8.85AV + 317.0
	Automatic	Neither	Yes	No	--	8.85AV + 401.0
	Automatic	Neither	Yes	Yes	--	9.25AV + 475.4
	Automatic	Compact	No	--	13.10AV + 367.0	11.80AV + 339.2
	Automatic	Compact	Yes	--	--	11.80AV + 423.2
	Automatic	Built-in	No	--	--	9.40AV + 336.9
	Automatic	Built-in	Yes	No	--	9.40AV + 420.9
	Automatic	Built-in	Yes	Yes	--	9.83AV + 499.9
Refrigerator-freezers Side-by-side	Automatic	Neither	No	--	4.91AV+507.5	8.51AV + 297.8
	Automatic	Neither	Yes	No	--	8.51AV + 381.8
	Automatic	Neither	Yes	Yes	10.10AV + 406.0	8.54AV + 432.8
	Automatic	Compact	No	--	7.60AV + 501.0	6.82AV + 456.9
	Automatic	Compact	Yes	--	--	6.82AV + 540.9
	Automatic	Built-in	No	--	--	10.22AV + 357.4
	Automatic	Built-in	Yes	No	--	10.22AV + 441.4
	Automatic	Built-in	Yes	Yes	--	10.25AV + 502.6
Refrigerator-freezers Top-Freezer	Automatic	Neither	No	--	9.80AV + 276.0	8.07AV + 233.7
	Automatic	Neither	Yes	No	--	8.07AV + 317.7
	Automatic	Neither	Yes	Yes	10.20AV + 356.0	8.40AV + 385.4
	Automatic	Compact	No	--	12.70AV + 355.0	11.80AV + 339.2
	Automatic	Compact	Yes	--	--	11.80AV + 423.2
	Automatic	Built-in	No	--	--	9.15AV + 264.9
	Automatic	Built-in	Yes	No	--	9.15AV + 348.9
Freezers Upright Freezer	Manual	Neither	No	--	7.55AV + 258.3	5.57AV + 193.7
	Manual	Compact	--	--	9.78AV + 250.8	8.65AV + 225.7
	Automatic	Neither	No	--	12.43AV + 326.1	8.62AV + 228.3
	Automatic	Neither	Yes	--	--	8.62AV + 312.3
	Automatic	Compact	--	--	11.40AV + 391.0	10.17AV + 351.9
	Automatic	Built-in	No	--	--	9.86AV + 260.9
	Automatic	Built-in	Yes	--	--	9.86AV + 344.9
Freezers Chest Freezer	Manual	NOT Compact	No	--	--	7.29AV + 107.8
	Partial	NOT Compact	No	--	--	7.29AV + 107.8
	Automatic	NOT Compact	No	--	9.88AV + 143.7	10.24AV + 148.1
	--	Compact	--	--	10.45AV + 152.0	9.25AV + 136.8

Appliance	*Defrost*	*Compact, Built- in, Neither*	*Ice*		*Maximum Energy Consumption (kWh/year)*	
			Equipped with Automatic Ice Maker?	*Dispense Ice Through Door?*	*July 1, 2001[1]*	*Sept. 15, 2014[2]*
Freezers Neither Chest Freezer nor Upright Freezer	--	NOT Compact	No	--	--	7.29AV + 107.8

[1]AV = adjusted total volume, expressed in ft^3, as determined in 10 C.F.R., part 430, Appendices A1 and B1 of Subpart B, which is:
[1.44 x freezer volume (ft^3)] + refrigerator volume (ft^3) for refrigerators;
[1.63 x freezer volume (ft^3)] + refrigerator volume (ft^3) for refrigerator-freezers;
[1.73 x freezer volume (ft^3)] for freezers.
[2]AV = adjusted total volume, expressed in ft^3, as determined in 10 C.F.R., part 430, Appendices A and B of Subpart B.

Note: Maximum energy consumption standards for refrigerator-freezers with internal freezers are same as those for refrigerator-freezers with top-mounted freezers.

TABLE A-4
STANDARDS FOR COMMERCIAL REFRIGERATORS AND FREEZERS WITH A SELF-CONTAINED CONDENSING UNIT THAT ARE NOT COMMERCIAL HYBRID UNITS

	Condensing Unit Configuration	*Equipment Family*	*Rating Temperature (°F)*	*Operating Temperature (°F)*	*Equipment Class Designation**	*Maximum Daily Energy Consumption (kWh)*
Refrigerators and Freezers Effective January 1, 2010	Self-Contained (SC)	Vertical Closed Transparent (VCT)	38 (M) 0 (L)	≥ 32 < 32	VCT, SC, M VCT, SC, L	0.12 × V + 3.34 0.75 × V + 4.10
		Horizontal Closed Transparent (HCT)	38 (M) 0 (L)	≥ 32 < 32	HCT, SC, M HCT, SC, L	0.12 × V + 3.34 0.75 × V + 4.10
		Vertical Closed Solid (VCS)	38 (M) 0 (L)	≥ 32 < 32	VCS, SC, M VCS, SC, L	0.10 × V + 2.04 0.40 × V + 1.38
		Horizontal Closed Solid (HCS)	38 (M) 0 (L)	≥ 32 < 32	HCS, SC, M HCS, SC, L	0.10 × V + 2.04 0.40 × V + 1.38
		Service Over Counter (SOC)	38 (M) 0 (L)	≥ 32 < 32	SOC, SC, M SOC, SC, L	0.12 × V + 3.34 0.75 × V + 4.10
Refrigerators with transparent doors designed for pull-down temperature applications Effective January 1, 2010	Self-Contained (SC)	Vertical Closed Transparent (VCT)	38 (P)	≥ 32	VCT, SC, P	0.126 × V + 3.51
		Horizontal Closed Transparent (HCT)	38 (P)	≥ 32	HCT, SC, P	0.126 × V + 3.51
Refrigerators and Freezers without doors Effective January 1, 2012	Self-Contained (SC)	Vertical Open (VOP)	38 (M) 0 (L)	≥ 32 < 32	VOP, SC, M VOP, SC, L	1.74 × TDA + 4.71 4.37 × TDA +11.82
		Semi-vertical Open (SVO)	38 (M) 0 (L)	≥ 32 < 32	SVO, SC, M SVO, SC, L	1.73 × TDA + 4.59 4.34 × TDA +11.51
		Horizontal Open (HZO)	38 (M) 0 (L)	≥ 32 < 32	HZO, SC, M HZO, SC, L	0.77 × TDA + 5.55 1.92 × TDA + 7.08

* The meaning of the letters in this column is indicated in the *Condensing Unit Configuration*, *Equipment Family*, and *Rating Temperature (°F)* columns to the left.

TABLE A-5
STANDARDS FOR COMMERCIAL REFRIGERATORS AND FREEZERS WITH A REMOTE CONDENSING UNIT THAT ARE NOT COMMERCIAL HYBRID UNITS

Equipment Category	***Condensing Unit Configuration***	***Equipment Family***	***Rating Temperature (°F)***	***Operating Temperature (°F)***	***Equipment Class Designation****	***Maximum Daily Energy Consumption (kWh)***
Refrigerators and Freezers	Remote (RC)	Vertical Open (VOP)	38 (M) 0 (L)	≥ 32 < 32	VOP, RC, M VOP, RC, L	0.82 × TDA + 4.07 2.27 × TDA + 6.85
Effective January 1, 2012		Semi-vertical Open (SVO)	38 (M) 0 (L)	≥ 32 < 32	SVO, RC, M SVO, RC, L	0.83 × TDA + 3.18 2.27 × TDA + 6.85
		Horizontal Open (HZO)	38 (M) 0 (L)	≥ 32 < 32	HZO, RC, M HZO, RC, L	0.35 × TDA + 2.88 0.57 × TDA + 6.88
		Vertical Closed Transparent (VCT)	38 (M) 0 (L)	≥ 32 < 32	VCT, RC, M VCT, RC, L	0.22 × TDA + 1.95 0.56 × TDA + 2.61
		Horizontal Closed Transparent (HCT)	38 (M) 0 (L)	≥ 32 < 32	HCT, RC, M HCT, RC, L	0.16 × TDA + 0.13 0.34 × TDA + 0.26
		Vertical Closed Solid (VCS)	38 (M) 0 (L)	≥ 32 < 32	VCS, RC, M VCS, RC, L	0.11 × V + 0.26 0.23 × V + 0.54
		Horizontal Closed Solid (HCS)	38 (M) 0 (L)	≥ 32 < 32	HCS, RC, M HCS, RC, L	0.11 × V + 0.26 0.23 × V + 0.54
		Service Over Counter (SOC)	38 (M) 0 (L)	≥ 32 < 32	SOC, RC, M SOC, RC, L	0.51 × TDA + 0.11 1.08 × TDA + 0.22

* The meaning of the letters in this column is indicated in the *Condensing Unit Configuration, Equipment Family*, and *Rating Temperature (°F)* columns to the left.

TABLE A-7
STANDARDS FOR AUTOMATIC COMMERCIAL ICE MAKERS MANUFACTURED ON OR AFTER JANUARY 1, 2010

Equipment type	*Type of cooling*	*Harvest rate (lbs ice/24 hours)*	*Maximum energy use (kWh/100 lbs ice)*	*Maximum condenser water use* (gal/100 lbs ice)*
Ice Making Head	Water	< 500	7.80–0.0055H	200–0.022H.
Ice Making Head	Water	≥ 500 and < 1436	5.58–0.0011H	200–0.022H.
Ice Making Head	Water	≥ 1436	4.0	200–0.022H.
Ice Making Head	Air	< 450	10.26–0.0086H	Not applicable.
Ice Making Head	Air	≥ 450	6.89–0.0011H	Not applicable.
Remote Condensing (but not remote compressor)	Air	< 1000	8.85–0.0038H	Not applicable.
Remote Condensing (but not remote compressor)	Air	≥ 1000	5.1	Not applicable.
Remote Condensing and Remote Compressor	Air	< 934	8.85–0.0038H	Not applicable.
Remote Condensing and Remote Compressor	Air	≥ 934	5.3	Not applicable.
Self-Contained	Water	< 200	11. 40–0.019H	191–0.0315H.
Self-Contained	Water	≥ 200	7.6	191–0.0315H.
Self-Contained	Air	< 175	18.0–0.0469H	Not applicable.
Self-Contained	Air	≥ 175	9.8	Not applicable.
H Harvest rate in pounds per 24 hours. *Water use is for the condenser only and does not include potable water used to make ice.				

TABLE B-2
STANDARDS FOR ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONING HEAT PUMPS MANUFACTURED ON OR AFTER OCTOBER 1, 2000 AND BEFORE JUNE 1, 2014

Appliance	*Louvered Sides*	*Cooling Capacity (Btu/hr)*	*Minimum EER*
Room Air Conditioner	Yes	< 6,000	9.7
Room Air Conditioner	Yes	≥ 6,000 – 7,999	9.7
Room Air Conditioner	Yes	≥ 8,000 – 13,999	9.8
Room Air Conditioner	Yes	≥ 14,000 – 19,999	9.7
Room Air Conditioner	Yes	≥ 20,000	8.5
Room Air Conditioner	No	< 6,000	9.0
Room Air Conditioner	No	≥ 6,000 – 7,999	9.0
Room Air Conditioner	No	≥ 8,000 – 19,999	8.5
Room Air Conditioner	No	≥ 20,000	8.5
Room Air Conditioning Heat Pump	Yes	< 20,000	9.0
Room Air Conditioning Heat Pump	Yes	≥ 20,000	8.5
Room Air Conditioning Heat Pump	No	< 14,000	8.5
Room Air Conditioning Heat Pump	No	≥ 14,000	8.0
Casement-Only Room Air Conditioner	Either	Any	8.7
Casement-Slider Room Air Conditioner	Either	Any	9.5

TABLE B-3
STANDARDS FOR ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONING HEAT PUMPS
MANUFACTURED ON OR AFTER JUNE 1, 2014

Appliance	*Louvered Sides*	*Cooling Capacity (Btu/hr)*	*Minimum Combined EER*
Room Air Conditioner	Yes	< 6,000	11.0
Room Air Conditioner	Yes	≥ 6,000 – 7,999	11.0
Room Air Conditioner	Yes	≥ 8,000 – 13,999	10.9
Room Air Conditioner	Yes	≥ 14,000 – 19,999	10.7
Room Air Conditioner	Yes	≥ 20,000 – 27,999	9.4
Room Air Conditioner	Yes	≥ 28,000	9.0
Room Air Conditioner	No	< 6,000	10.0
Room Air Conditioner	No	≥6,000 – 7,999	10.0
Room Air Conditioner	No	≥ 8,000 – 10,999	9.6
Room Air Conditioner	No	≥ 11,000 – 13,999	9.5
Room Air Conditioner	No	≥ 14,000 – 19,999	9.3
Room Air Conditioner	No	≥ 20,000	9.4
Room Air Conditioning Heat Pump	Yes	< 20,000	9.8
Room Air Conditioning Heat Pump	Yes	≥ 20,000	9.3
Room Air Conditioning Heat Pump	No	< 14,000	9.3
Room Air Conditioning Heat Pump	No	≥ 14,000	8.7
Casement-Only Room Air Conditioner	Either	Any	9.5
Casement-Slider Room Air Conditioner	Either	Any	10.4

TABLE B-6 STANDARDS FOR STANDARD SIZE PACKAGED TERMINAL AIR CONDITIONERS AND STANDARD SIZE PACKAGED TERMINAL HEAT PUMPS MANUFACTURED ON OR AFTER OCTOBER 8, 2012

Appliance	*Cooling Capacity (Btu/hour)*	*Minimum Efficiency*	
		Minimum EER	*Minimum COP*
Packaged Terminal Air Conditioners	< 7,000	11.7	—
	≥ 7,000 < 15,000	13.8 – (0.300 x Cap[1])	—
	≥ 15,000	9.3	—
Packaged Terminal Heat Pumps	< 7,000	11.9	3.3
	≥ 7,000 < 15,000	14.0 – (0.300 x Cap[1])	3.7 - (0.052 x Cap[1])
	≥ 15,000	9.5	2.9

[1] Cap means cooling capacity in thousand British thermal units per hour (Btu/h) at 95°F outdoor dry-bulb temperature.

TABLE C-2
STANDARDS FOR SINGLE PHASE AIR-COOLED AIR CONDITIONERS WITH COOLING CAPACITY LESS THAN 65,000 BTU PER HOUR AND SINGLE-PHASE AIR-SOURCE HEAT PUMPS WITH COOLING CAPACITY LESS THAN 65,000 BTU PER HOUR, NOT SUBJECT TO EPACT

Appliance	*Minimum Efficiency*					
	Effective January 23, 2006		*Effective January 1, 2015*			
	Minimum SEER	*Minimum HSPF*	*Minimum SEER*	*Minimum HSPF*	*Minimum EER*	*Average Off-Mode Power Consumption $P_{w,off}$ (watts)*
Split system air conditioners with rated cooling capacity < 45,000 Btu/hour[1]	13.0	—	14.0	—	12.2	30
Split system air conditioners with rated cooling capacity ≥ 45,000 Btu/hour[1]			14.0	—	11.7	30
Split system heat pumps	13.0	7.7	14.0	8.2	—	33
Single package air conditioners[1]	13.0	—	14.0	—	11.0	30
Single package heat pumps	13.0	7.7	14.0	8.0	—	33
Space constrained air conditioners – split system	12.0		12.0	—	—	30
Space constrained heat pumps – split system	12.0	7.4	12.0	7.4	—	33
Space constrained air conditioners – single package	12.0		12.0	—	—	30
Space constrained heat pumps – single package	12.0	7.4	12.0	7.4	—	33
Small duct, high velocity air conditioner systems	13.0		13.0	—	—	30
Small duct, high velocity heat pump systems	13.0	7.7	13.0	7.7	—	30

[1] See 10 C.F.R. section 430.32(c) for less stringent federal standards applicable to these units that are manufactured on or after January 1, 2015 and installed in states other than Arizona, California, Nevada, or New Mexico

TABLE C-3
STANDARDS FOR AIR-COOLED AIR CONDITIONERS AND AIR-SOURCE HEAT PUMPS SUBJECT TO EPACT
(STANDARDS EFFECTIVE JANUARY 1, 2010 DO NOT APPLY TO SINGLE PACKAGE VERTICAL AIR CONDITIONERS)

Appliance	*Cooling Capacity (Btu/hr)*	*System Type*	*Minimum Efficiency*		
			Effective June 15, 2008	*Effective January 1, 2010*	
				Air Conditioners	*Heat Pumps*
Air-cooled unitary air conditioners and heat pumps (cooling mode)	< 65,000 *	Split system	13.0 SEER		
	< 65,000 *	Single package	13.0 SEER		
	≥ 65,000 and < 135,000	All		11.2 EER[3] 11.0 EER[4]	11.0 EER[3] 10.8 EER[4]
	≥ 135,000 and < 240,000	All		11.0 EER[3] 10.8 EER[4]	10.6 EER[3] 10.4 EER[4]
	≥ 240,000 and < 760,000	All		10.0 EER[3] 9.8 EER[4]	9.5 EER[3] 9.3 EER[4]
Air-cooled unitary air-conditioning heat pumps (heating mode)	< 65,000 *	Split system	7.7 HSPF		
	< 65,000 *	Single package	7.7 HSPF		
	≥ 65,000 and < 135,000	All		3.3 COP	
	≥ 135,000 and < 240,000	All		3.2 COP	
	≥ 240,000 and < 760,000	All		3.2 COP	

* Three phase models only.
[3] Applies to equipment that has electric resistance heat or no heating.
[4] Applies to equipment with all other heating-system types that are integrated into the unitary equipment.

TABLE C-4
STANDARDS FOR WATER-COOLED AIR CONDITIONERS, EVAPORATIVELY COOLED AIR CONDITIONERS, AND WATER-SOURCE HEAT PUMPS

Appliance	*Cooling Capacity (Btu per hour)*	*Minimum Efficiency*							
		Effective Prior to October 29, 2012		*Effective January 10, 2011*		*Effective †October 29, 2012 or ††October 29, 2013*		*Effective *June 1, 2013 or **June 1, 2014*	
		Minimum EER	*COP*	*Minimum EER*	*COP*	*Minimum EER*	*COP*	*Minimum EER*	*COP*
Water-cooled air conditioners and evaporatively cooled air	< 17,000	12.1	—						
Water-source heat pumps	< 17,000	11.2	4.2						
Water-source VRF multi-split heat pumps	< 17,000	—	4.2			12.0[1]†	4.2		
Water-cooled air conditioners and evaporatively cooled air	≥17,000 and < 65,000	12.1	—						
Water-source heat pumps, including VRF	≥17,000 and < 65,000	12.0	4.2						
Water-cooled air conditioners and evaporatively cooled air	≥65,000 and < 135,000	11.5[1]	–					12.1[1]*	—
Water-source heat pumps, including VRF	≥65,000 and < 135,000	12.0	4.2					11.9*	4.2
Water-cooled air conditioners	≥135,000 and < 240,000	11.0	—					12.5[1]**	—
Evaporatively cooled air conditioners	≥135,000 and < 240,000	11.0	—					12.0[1]**	—
Water-source heat pumps	≥135,000 and < 240,000	11.0	2.9					12.3**	2.9
Water-source VRF multi-split heat pumps	≥135,000 and < 760,000					10.0[1]††	3.9††		
Water-cooled air conditioners	≥240,000 and < 760,000	11.0[1]	–	11.0[1]	—			12.4[1]**	—
Evaporatively cooled air conditioners	≥240,000 and < 760,000	11.0[1]	–	11.0[1]	—			11.9[1]**	—
Water-source heat pumps	≥240,000 and < 760,000	11.0[1]	–	11.0[1]	—			12.2**	—

[1] Deduct 0.2 from the required EER for units with heating sections other than electric resistance heat. For VRF multi-split heat pumps this applies to units with heat recovery.

TABLE C-5
STANDARDS FOR SINGLE PACKAGE VERTICAL AIR CONDITIONERS AND SINGLE PACKAGE VERTICAL HEAT PUMPS MANUFACTURED ON OR AFTER JANUARY 1, 2010

Appliance	*Cooling Capacity (BTU/hr)*	*System Type*	*Minimum Efficiency*	
			Cooling Mode	*Heating Mode*
Single package vertical air conditioners	< 65,000	Single-phase	9.0 EER	N/A
	< 65,000	3-phase	9.0 EER	N/A
	≥ 65,000 and < 135,000	All	8.9 EER	N/A
	≥ 135,000 and < 240,000	All	8.6 EER	N/A
Single package vertical heat pumps	< 65,000	Single-phase	9.0 EER	3.0 COP
	< 65,000	3-phase	9.0 EER	3.0 COP
	≥ 65,000 and < 135,000	All	8.9 EER	3.0 COP
	≥ 135,000 and < 240,000	All	8.6 EER	2.9 COP

TABLE D-2
STANDARDS FOR DEHUMIDIFIERS

Product capacity (pint/day)	*Minimum energy factor (liters/kWh)*	
	Effective October 1, 2007	*Effective October 1, 2012*
25.00 or less	1.00	1.35
25.01 – 35.00	1.20	1.35
35.01 – 45.00	1.30	1.50
45.01 – 54.00	1.30	1.60
54.01 – 74.99	1.50	1.70
75.00 or more	2.25	2.50

TABLE E-2
STANDARDS FOR GAS WALL FURNACES, FLOOR FURNACES, AND ROOM HEATERS

Appliance	*Design Type*	*Capacity (Btu per hour)*	*Minimum AFUE (%)*	
			Effective Before April 16, 2013	*Effective On or After April 16, 2013*
Wall furnace	Fan	≤ 42,000	73	75
Wall furnace	Fan	> 42,000	74	76
Wall furnace	Gravity	≤10,000	59	65
Wall furnace	Gravity	> 10,000 and ≤ 12,000	60	
Wall furnace	Gravity	> 12,000 and ≤ 15,000	61	
Wall furnace	Gravity	> 15,000 and ≤ 19,000	62	
Wall furnace	Gravity	> 19,000 and ≤ 27,000	63	
Wall furnace	Gravity	> 27,000 and ≤ 46,000	64	66
Wall furnace	Gravity	> 46,000	65	67
Floor furnace	All	≤ 37,000	56	57
Floor furnace	All	> 37,000	57	58
Room heater	All	≤ 18,000	57	61
Room heater	All	> 18,000 and ≤ 20,000	58	
Room heater	All	> 20,000 and ≤ 27,000	63	66
Room heater	All	> 27,000 and ≤ 46,000	64	67
Room heater	All	> 46,000	65	68

TABLE E-3
STANDARDS FOR GAS- AND OIL-FIRED CENTRAL BOILERS < 300,000 BTU/HR INPUT AND ELECTRIC RESIDENTIAL BOILERS

Appliance	*Minimum AFUE (%)*	
	Effective January 1, 1992	
	75	*Effective September 1, 2012*
Gas steam boilers with single phase electrical supply	80	80 [1]
Gas hot water boilers with single phase electrical supply	—	82 [1,2]
Oil steam boilers with single phase electrical supply	—	82
Oil hot water boilers with single phase electrical supply	—	84 [2]
Electric steam residential boilers	—	NONE
Electric hot water residential boilers	80	NONE [2]
All other boilers with single phase electrical supply	—	—

[1] No constant burning pilot light design standard effective September 1, 2012.
[2] Automatic means for adjusting temperature design standard effective September 1, 2012. (Boilers equipped with tankless domestic water heating coils do not need to comply with this requirement.)

TABLE E-5
STANDARDS FOR GAS- AND OIL-FIRED CENTRAL FURNACES

Appliance	*Rated Input (Btu/hr)*	*Minimum Thermal Efficiency*
Gas central furnaces	≥ 225,000	80
Oil central furnaces	≥ 225,000	81

TABLE F-2
STANDARDS FOR LARGE WATER HEATERS EFFECTIVE OCTOBER 29, 2003

Appliance	*Input to Volume Ratio*	*Size (Volume)*	*Minimum Thermal Efficiency (%)*	*Maximum Standby Loss[1,2]*
Gas storage water heaters	< 4,000 Btu/hr/gal	any	80	Q/800 + 110$(V_r)^{1/2}$ Btu/hr
Gas instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	Q/800 + 110$(V_r)^{1/2}$ Btu/hr
Gas hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	Q/800 + 110$(V_r)^{1/2}$ Btu/hr
Oil storage water heaters	< 4,000 Btu/hr/gal	any	78	Q/800 + 110$(V_r)^{1/2}$ Btu/hr
Oil instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	Q/800 + 110$(V_r)^{1/2}$ Btu/hr
Oil hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	Q/800 + 110$(V_r)^{1/2}$ Btu/hr
Electric storage water heaters	< 4,000 Btu/hr/gal	Any	–	0.3 + 27/V_m %/hr

[1] Standby loss is based on a 70° F temperature difference between stored water and ambient requirements. In the standby loss equations, V_r is the rated volume in gallons, V_m is the measured volume in gallons, and Q is the nameplate input rate in Btu/hr.

[2] Water heaters and hot water supply boilers having more than 140 gallons of storage capacity are not required to meet the standby loss requirement if the tank surface is thermally insulated to R-12.5, if a standing pilot light is not installed, and for gas- or oil-fired storage water heaters, there is a flue damper or fan-assisted combustion.

TABLE F-3
STANDARDS FOR SMALL FEDERALLY REGULATED WATER HEATERS

Appliance	*Rated Storage Volume (gallons)*	*Minimum Energy Factor*	
		Effective January 20, 2004	*Effective April 16, 2015*
Gas-fired storage-type water heaters	≤ 55	0.67 – (.0019 x V)	0.675−(0.0015 × V)
	> 55		0.8012−(0.00078 × V)
Oil-fired water heaters (storage and instantaneous)	Any	0.59 – (.0019 x V)	0.68 – (.0019 x V)
Electric storage water heaters (excluding tabletop water heaters)	≤ 55	0.97 – (.00132 x V)	0.960−(0.0003 × V)
	> 55		2.057−(0.00113 × V)
Electric tabletop water heaters	Any	0.93 – (.00132 x V)	0.93 – (.00132 x V)
Gas-fired instantaneous water heaters	Any	0.62 – (.0019 x V)	0.82 – (.0019 x V)
Electric instantaneous water heaters (excluding tabletop water heaters)	Any	0.93 – (.00132 x V)	0.93 – (.00132 x V)
Heat pump water heaters	Any	0.97 – (.00132 x V)	0.97 – (.00132 x V)
V = Rated storage volume in gallons.			

TABLE H-1
STANDARDS FOR PLUMBING FITTINGS

Appliance	*Maximum Flow Rate*
Showerheads	2.5 gpm at 80 psi
Lavatory faucets	2.2 gpm at 60 psi
Kitchen faucets	2.2 gpm at 60 psi
Replacement aerators	2.2 gpm at 60 psi
Wash fountains	$2.2 \times \frac{\text{rim space (inches)}}{20}$ gpm at 60 psi
Metering faucets	0.25 gallons/cycle[1,2]
Metering faucets for wash fountains	$0.25 \times \frac{\text{rim space (inches)}}{20}$ gpm at 60 psi[1,2]

1 **Sprayheads with independently controlled orifices and metered controls.** The maximum flow rate of each orifice that delivers a pre-set volume of water before gradually shutting itself off shall not exceed the maximum flow rate for a metering faucet.

2 **Sprayheads with collectively controlled orifices and metered controls.** The maximum flow rate of a sprayhead that delivers a pre-set volume of water before gradually shutting itself off shall be the product of (a) the maximum flow rate for a metering faucet and (b) the number of component lavatories (rim space of the lavatory in inches (millimeters) divided by 20 inches (508 millimeters)).

TABLE J-1
STANDARDS FOR FLUORESCENT LAMP BALLASTS AND REPLACEMENT FLUORESCENT LAMP BALLASTS

Application for Operation of	*Ballast Input Voltage*	*Total Nominal Lamp Watts*	*Minimum Ballast Efficacy Factor*	
one F40T12 lamp	120 or 277	40	2.29[1]	1.805[2]
two F40T12 lamps	120	80	1.17[1]	1.060[2]
	277	80	1.17[1]	1.050[2]
two F96T12 lamps	120 or 277	150	0.63[1]	0.570[2]
two F96T12HO lamps	120 or 277	220	0.39[1]	0.390[2]

[1] For fluorescent lamp ballasts manufactured on or after April 1, 2005; sold by the manufacturer on or after July 1, 2005; or incorporated into a luminaire by a luminaire manufacturer on or after April 1, 2006.
[2] For fluorescent lamp ballasts designed, marked, and shipped as replacement ballasts.

TABLE J-2
STANDARDS FOR FLUORESCENT LAMP BALLASTS[1]

Application for Operation of	*Ballast Input Voltage*	*Total Nominal Lamp Watts*	*Minimum Ballast Efficacy Factor*
one F34T12 lamp	120 or 277	34	2.61
two F34T12 lamps	120 or 277	68	1.35
two F96T12/ES lamps	120 or 277	120	0.77
two F96T12HO/ES lamps	120 or 277	190	0.42

[1] For fluorescent lamp ballasts manufactured on or after July 1, 2009; sold by the manufacturer on or after October 1, 2009; or fluorescent lamp ballasts incorporated into a luminaire by a luminaire manufacturer on or after July 1, 2010.

TABLE K-1
STANDARDS FOR FEDERALLY REGULATED GENERAL SERVICE FLUORESCENT LAMPS MANUFACTURED BEFORE JULY 15, 2012

Appliance	*Nominal Lamp Wattage*	*Minimum Color Rendering Index (CRI)*	*Minimum Average Lamp Efficacy (LPW)*
4-foot medium bi-pin lamps	> 35	69	75.0
	≤ 35	45	75.0
2-foot U-shaped lamps	> 35	69	68.0
	≤ 35	45	64.0
8-foot slimline lamps	> 65	69	80.0
	≤ 65	45	80.0
8-foot high output lamps	> 100	69	80.0
	≤ 100	45	80.0

TABLE K-2
STANDARDS FOR FEDERALLY REGULATED GENERAL SERVICE FLUORESCENT LAMPS MANUFACTURED ON OR AFTER JULY 15, 2012

Appliance	*Correlated Color Temperature*	*Minimum Average Lamp Efficacy (LPW)*
4-foot medium bipin lamps	≤ 4,500K	89
	> 4,500K and ≤ 7,000K	88
2-foot U-shaped lamps	≤ 4,500K	84
	> 4,500K and ≤ 7,000K	81
8-foot slimline lamps	≤ 4,500K	97
	> 4,500K and ≤ 7,000K	93
8-foot high output lamps	≤ 4,500K	92
	> 4,500K and ≤ 7,000K	88
4-foot miniature bipin standard output	≤ 4,500K	86
	> 4,500K and ≤ 7,000K	81
4-foot miniature bipin high output	≤ 4,500K	76
	> 4,500K and ≤ 7,000K	72

TABLE K-3
STANDARDS FOR FEDERALLY REGULATED INCANDESCENT REFLECTOR LAMPS MANUFACTURED BEFORE JULY 15, 2012

Nominal Lamp Wattage	*Minimum Average Lamp Efficacy (LPW)*
40-50	10.5
51-66	11.0
67-85	12.5
86-115	14.0
116-155	14.5
156-205	15.0

TABLE K-4
STANDARDS FOR FEDERALLY REGULATED INCANDESCENT REFLECTOR LAMPS MANUFACTURED ON OR AFTER JULY 15, 2012

Lamp Spectrum	*Lamp Diameter (inches)*	*Rated Voltage*	*Minimum Average Lamp Efficacy (LPW)*[1]
Standard Spectrum	> 2.5	≥ 125	$6.8 \times P^{0.27}$
		< 125	$5.9 \times P^{0.27}$
	≤ 2.5	≥ 125	$5.7 \times P^{0.27}$
		< 125	$5.0 \times P^{0.27}$
Modified Spectrum	> 2.5	≥ 125	$5.8 \times P^{0.27}$
		< 125	$5.0 \times P^{0.27}$
	≤ 2.5	≥ 125	$4.9 \times P^{0.27}$
		< 125	$4.2 \times P^{0.27}$
[1]P = Rated Lamp Wattage, in Watts			

TABLE K-5
STANDARDS FOR MEDIUM BASE COMPACT FLUORESCENT LAMPS

Factor	*Requirements*
Lamp Power (Watts) and Configuration[1]	*Minimum Efficacy: lumens/watt (Based upon initial lumen data)*[2]
Bare Lamp: Lamp Power < 15 Lamp Power ≥ 15	 45.0 60.0
Covered Lamp (no reflector) Lamp Power < 15 15 ≥ Lamp Power < 19 19 ≥ Lamp Power < 25 Lamp Power ≥ 25	 40.0 48.0 50.0 55.0
1,000-hour Lumen Maintenance	The average of at least 5 lamps must be a minimum 90% of initial (100-hour) lumen output @ 1,000 hours of rated life.
Lumen Maintenance	80% of initial (100-hour) rating at 40 percent of rated life (per ANSI C78.5 Clause 4.10).
Rapid Cycle Stress Test	Per ANSI C78.5 and IESNA LM-65 (Clauses 2, 3, 5, and 6) *Exception:* Cycle times must be 5 minutes on, 5 minutes off. Lamp will be cycled once for every two hours of rated life. At least 5 lamps *must meet or exceed* the minimum number of cycles.
Average Rated Lamp Life	≥ 6,000 hours as declared by the manufacturer on the packaging. 80% of rated life, statistical methods may be used to confirm lifetime claims based on sampling performance.
[1] Take performance and electrical requirements at the end of the 100-hour aging period according to ANSI Standard C78.5. The lamp efficacy shall be the average of the lesser of the lumens per watt measured in the base up and/or other specified positions. Use wattages placed on packaging to select proper specification efficacy in this table, not measured wattage. Labeled wattages are for reference only.	
[2] Efficacies are based on measured values for lumens and wattages from pertinent test data. Wattages and lumens placed on packages may not be used in calculation and are not governed by this specification. For multi-level or dimmable systems, measurements shall be at the highest setting. Acceptable measurement error is ±3%.	

TABLE K-6
STANDARDS FOR FEDERALLY REGULATED GENERAL SERVICE INCANDESCENT LAMPS

Rated Lumen Ranges	*Maximum Rate Wattage*	*Minimum Rate Lifetime*	*Effective Date*
1490-2600	72	1,000 hours	January 1, 2012
1050 – 1489	53	1,000 hours	January 1, 2013
750 – 1049	43	1,000 hours	January 1, 2014
310 – 749	29	1,000 hours	January 1, 2014

TABLE K-7
STANDARDS FOR FEDERALLY REGULATED MODIFIED SPECTRUM GENERAL SERVICE INCANDESCENT LAMPS

Rated Lumen Ranges	*Maximum Rate Wattage*	*Minimum Rate Lifetime*	*Effective Date*
1118-1950	72	1,000 hours	January 1, 2012
788-1117	53	1,000 hours	January 1, 2013
563-787	43	1,000 hours	January 1, 2014
232-562	29	1,000 hours	January 1, 2014

TABLE M-1
STANDARDS FOR TRAFFIC SIGNALS FOR VEHICLE AND PEDESTRIAN CONTROL

Appliance	*Maximum Wattage (at 74°C)*	*Nominal Wattage (at 25°C)*
Traffic Signal Module Type:		
12-inch; Red Ball	17	11
8-inch; Red Ball	13	8
12-inch; Red Arrow	12	9
12-inch; Green Ball	15	15
8-inch; Green Ball	12	12
12-inch; Green Arrow	11	11
Pedestrian Module Type:		
Combination Walking Man/Hand	16	13
Walking Man	12	9
Orange Hand	16	13

TABLE O
STANDARDS FOR DISHWASHERS

Appliance	*Effective January 1, 2010*		*Effective May 30, 2013*	
	Maximum Energy Use (kWh/year)	*Maximum Water Use (gallons/cycle)*	*Maximum Energy Use (kWh/year)*	*Maximum Water Use (gallons/cycle)*
Compact dishwashers	260	4.5	222	3.5
Standard dishwashers	355	6.5	307	5.0

TABLE P-1
STANDARDS FOR RESIDENTIAL CLOTHES WASHERS MANUFACTURED ON OR AFTER JANUARY 1, 2007 AND MANUFACTURED BEFORE MARCH 7, 2015

Appliance	*Minimum Modified Energy Factor Effective January 1, 2007*	*Maximum Water Factor Effective January 1, 2011*
Top-loading compact clothes washers	0.65	--
Top-loading standard clothes washers	1.26	9.5
Top-loading, semi-automatic	N/A[1]	--
Front-loading clothes washers	1.26	9.5
Suds-saving	N/A[1]	--

[1] Must have an unheated rinse water option.

TABLE P-2
STANDARDS FOR RESIDENTIAL CLOTHES WASHERS MANUFACTURED ON OR AFTER MARCH 7, 2015

Appliance	*Minimum Integrated Modified Energy Factor*		*Maximum Integrated Water Factor*	
	March 7, 2015	*January 1, 2018*	*March 7, 2015*	*January 1, 2018*
Top-loading, Compact	0.86	1.15	14.4	12.0
Top-loading, Standard	1.29	1.57	8.4	6.5
Front-loading, Compact	1.13	1.13	8.3	8.3
Front-loading, Standard	1.84	1.84	4.7	4.7

TABLE P-3
STANDARDS FOR CLOTHES WASHERS

Appliance	Minimum Modified Energy Factor		Maximum Water Factor	
	Effective January 1, 2007	Effective January 8, 2013	Effective January 1, 2007	Effective January 8, 2013
Top-loading clothes washers	1.26	1.60	9.5	8.5
Front-loading clothes washers	1.26	2.00	9.5	5.5

TABLE Q-1
STANDARDS FOR CLOTHES DRYERS MANUFACTURED ON OR AFTER MAY 14, 1994
AND BEFORE JANUARY 1, 2015

Appliance	Minimum Energy Factor (lbs/kWh)
Electric, standard clothes dryers	3.01
Electric, compact, 120-volt clothes dryers	3.13
Electric, compact, 240-volt clothes dryers	2.90
Gas clothes dryers	2.67

TABLE S-1
STANDARDS FOR ELECTRIC MOTORS

Motor Horsepower/Standard Kilowatt Equivalent	Minimum Nominal Full-Load Efficiency					
	Open Motors			Enclosed Motors		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
1/0.75	80.0	82.5	. . .	80.0	82.5	75.5
1.5/1.1	84.0	84.0	82.5	85.5	84.0	82.5
2/1.5	85.5	84.0	84.0	86.5	84.0	84.0
3/2.2	86.5	86.5	84.0	87.5	87.5	85.5
5/3.7	87.5	87.5	85.5	87.5	87.5	87.5
7.5/5.5	88.5	88.5	87.5	89.5	89.5	88.5
10/7.5	90.2	89.5	88.5	89.5	89.5	89.5
15/11	90.2	91.0	89.5	90.2	91.0	90.2
20/15	91.0	91.0	90.2	90.2	91.0	90.2
25/18.5	91.7	91.7	91.0	91.7	92.4	91.0
30/22	92.4	92.4	91.0	91.7	92.4	91.0
40/30	93.0	93.0	91.7	93.0	93.0	91.7
50/37	93.0	93.0	92.4	93.0	93.0	92.4
60/45	93.6	93.6	93.0	93.6	93.6	93.0
75/55	93.6	94.1	93.0	93.6	94.1	93.0
100/75	94.1	94.1	93.0	94.1	94.5	93.6
125/90	94.1	94.5	93.6	94.1	94.5	94.5
150/110	94.5	95.0	93.6	95.0	95.0	94.5
200/150	94.5	95.0	94.5	95.0	95.0	95.0

TABLE T-3
STANDARDS FOR LOW-VOLTAGE DRY-TYPE DISTRIBUTION TRANSFORMERS

Single phase			Three phase		
kVA	Efficiency (%)[1]		kVA	Efficiency (%)[1]	
	Effective January 1, 2007	Effective January 1, 2016		Effective January 1, 2007	Effective January 1, 2016
15	97.7	97.70	15	97.0	97.89
25	98.0	98.00	30	97.5	98.23
37.5	98.2	98.20	45	97.7	98.40
50	98.3	98.30	75	98.0	98.60
75	98.5	98.50	112.5	98.2	98.74
100	98.6	98.60	150	98.3	98.83
167	98.7	98.70	225	98.5	98.94
250	98.8	98.80	300	98.6	99.02
333	98.9	98.90	500	98.7	99.14
			750	98.8	99.23
			1000	98.9	99.28

[1] Efficiencies are determined at the following reference conditions:
(1) for no-load losses, at the temperature of 20°C, and (2) for load-losses, at the temperature of 75°C and 35 percent of nameplate load.
(Source: Table 4–2 of NEMA Standard TP–1–2002, "Guide for Determining Energy Efficiency for Distribution Transformers.")

TABLE T-4
STANDARDS FOR LIQUID-IMMERSED DISTRIBUTION TRANSFORMERS

Single phase			Three phase		
kVA	Efficiency (%)[1]		kVA	Efficiency (%)[1]	
	Effective January 1, 2007	*Effective January 1, 2016*		*Effective January 1, 2007*	*Effective January 1, 2016*
10	98.62	98.70	15	98.36	98.65
15	98.76	98.82	30	98.62	98.83
25	98.91	98.95	45	98.76	98.92
37.5	99.01	99.05	75	98.91	99.03
50	99.08	99.11	112.5	99.01	99.11
75	99.17	99.19	150	99.08	99.16
100	99.23	99.25	225	99.17	99.23
167	99.25	99.33	300	99.23	99.27
250	99.32	99.39	500	99.25	99.35
333	99.36	99.43	750	99.32	99.40
500	99.42	99.49	1000	99.36	99.43
667	99.46	99.52	1500	99.42	99.48
833	99.49	99.55	2000	99.46	99.51
			2500	99.49	99.53

[1] Note: All efficiency values are at 50 percent of nameplate-rated load, determined when tested according to the test procedure in Section 1604(t).

TABLE T-5
STANDARDS FOR MEDIUM-VOLTAGE DRY-TYPE DISTRIBUTION TRANSFORMERS MANUFACTURED ON OR AFTER JANUARY 1, 2010 AND BEFORE JANUARY 1, 2016

Single phase				*Three phase*			
BIL kVA	***20-45 kV Efficiency[1] (%)***	***46-95 kV efficiency[1] (%)***	***≥ 96 kV efficiency[1] (%)***	***BIL kVA***	***20-45 kV Efficiency[1] (%)***	***46-95 kV efficiency[1] (%)***	***≥ 96 kV efficiency[1] (%)***
15	98.10	97.86		15	97.50	97.18	
25	98.33	98.12		30	97.90	97.63	
37.5	98.49	98.30		45	98.10	97.86	
50	98.60	98.42		75	98.33	98.12	
75	98.73	98.57	98.53	112.5	98.49	98.30	
100	98.82	98.67	98.63	150	98.60	98.42	
167	98.96	98.83	98.80	225	98.73	98.57	98.53
250	99.07	98.95	98.91	300	98.82	98.67	98.63
333	99.14	99.03	98.99	500	98.96	98.83	98.80
500	99.22	99.12	99.09	750	99.07	98.95	98.91
667	99.27	99.18	99.15	1000	99.14	99.03	98.99
833	99.31	99.23	99.20	1500	99.22	99.12	99.09
				2000	99.27	99.18	99.15
				2500	99.31	99.23	99.20

[1] All efficiency values are at 50 percent of nameplate rated load, determined when tested according to the test procedure in Section 1604(t).

TABLE T-6
STANDARDS FOR MEDIUM-VOLTAGE DRY-TYPE DISTRIBUTION TRANSFORMERS
MANUFACTURED ON OR AFTER JANUARY 1, 2016

Single phase				*Three phase*			
BIL kVA	*20-45 kV Efficiency[1] (%)*	*46-95 kV efficiency[1] (%)*	*≥ 96 kV efficiency[1] (%)*	*BIL kVA*	*20-45 kV Efficiency[1] (%)*	*46-95 kV efficiency[1] (%)*	*≥ 96 kV efficiency[1] (%)*
15	98.10	97.86		15	97.50	97.18	
25	98.33	98.12		30	97.90	97.63	
37.5	98.49	98.30		45	98.10	97.86	
50	98.60	98.42		75	98.33	98.13	
75	98.73	98.57	98.53	112.5	98.52	98.36	
100	98.82	98.67	98.63	150	98.65	98.51	
167	98.96	98.83	98.80	225	98.82	98.69	98.57
250	99.07	98.95	98.91	300	98.93	98.81	98.69
333	99.14	99.03	98.99	500	99.09	98.99	98.89
500	99.22	99.12	99.09	750	99.21	99.12	99.02
667	99.27	99.18	99.15	1000	99.28	99.20	99.11
833	99.31	99.23	99.20	1500	99.37	99.30	99.21
				2000	99.43	99.36	99.28
				2500	99.47	99.41	99.33

[1] All efficiency values are at 50 percent of nameplate rated load, determined when tested according to the test procedure in Section 1604(t).

TABLE U-1
STANDARDS FOR CLASS A EXTERNAL POWER SUPPLIES THAT ARE FEDERALLY REGULATED

Nameplate Output	***Minimum Efficiency in Active Mode (Decimal equivalent of a Percentage)***
< 1 watt	0.5 * Nameplate Output
≥ 1 and ≤ 51 watts	0.09*Ln(Nameplate Output) + 0.5
> 51 watts	0.85
	Maximum Energy Consumption in No-Load Mode
≤ 250 watts	0.5 watts
Where Ln (Nameplate Output) = Natural Logarithm of the nameplate output expressed in watts.	

TABLE A-9
STANDARDS FOR WINE CHILLERS

Appliance	*Maximum Annual Energy Consumption (kWh)*
Wine chillers with manual defrost	13.7V + 267
Wine chillers with automatic defrost	17.4V + 344
V = volume in ft^3.	

TABLE A-10
STANDARDS FOR FREEZERS THAT ARE CONSUMER PRODUCTS

Appliance	*Maximum Annual Energy Consumption (kWh)*
Upright Freezers with manual defrost	7.55AV + 258.3
Upright Freezers with automatic defrost	12.43AV + 326.1
Chest Freezers	9.88AV + 143.7
AV = adjusted total volume, expressed in ft^3, which is 1.73 x freezer volume (ft^3).	

TABLE A-12
STANDARDS FOR REFRIGERATED CANNED AND BOTTLED BEVERAGE VENDING MACHINES

Appliance	*Doors*	*Maximum Daily Energy Consumption (kWh)*	
		January 1, 2006	*January 1, 2007*
Refrigerated canned and bottled beverage vending machines when tested at 90° F ambient temperature except multi-package units	Not applicable	0.55(8.66 + (0.009 × C))	0.55(8.66 + (0.009 × C))
Refrigerated multi-package canned and bottled beverage vending machines when tested at 75° F ambient temperature	Not applicable	0.55(8.66 + (0.009 × C))	0.55(8.66 + (0.009 × C))
V = total volume (ft^3) AV = Adjusted Volume = [1.63 x freezer volume (ft^3)] + refrigerator volume (ft^3) C=Rated capacity (number of 12-ounce cans)			

TABLE C-7
STANDARDS FOR GROUND WATER-SOURCE AND GROUND-SOURCE HEAT PUMPS

Appliance	*Rating Condition*	*Minimum Standard*
Ground water-source heat pumps (cooling)	59°F entering water temperature	16.2 EER
Ground water-source heat pumps (heating)	50°F entering water temperature	3.6 COP
Ground-source heat pumps (cooling)	77°F entering brine temperature	13.4 EER
Ground-source heat pumps (heating)	32°F entering brine temperature	3.1 COP

TABLE C-8
STANDARDS FOR EVAPORATIVELY COOLED COMPUTER ROOM AIR CONDITIONERS

Appliance	*Cooling Capacity (Btu/hr)*	*Minimum EER (Btu/watt-hour)*	
		Air-Cooled Effective January 1, 2006	*Water-Cooled, Glycol-Cooled, and Evaporatively-Cooled Effective October 29, 2006*
Computer room air conditioners	< 65,000	11.0	11.1
	≥ 65,000 and < 135,000	10.4	10.5
	≥ 135,000 and < 240,000	10.2	10.0

TABLE E-7
STANDARDS FOR BOILERS

Appliance	*Output (Btu/hr)*	*Standards*		
		Minimum AFUE %	*Minimum Combustion Efficiency % **	*Maximum Standby Loss (watts)*
Gas steam boilers with 3-phase electrical supply	< 300,000	75	—	—
All other boilers with 3-phase electrical supply	< 300,000	80	—	—
Natural gas, non-packaged boilers	≥ 300,000	—	80	147
LPG Non-packaged boilers	≥ 300,000	—	80	352
Oil, non-packaged boilers	≥ 300,000	—	83	—

*At both maximum and minimum rated capacity, as provided and allowed by the controls.

TABLE E-8
STANDARDS FOR FURNACES

Appliance	*Application*	*Minimum Efficiency %*
Central furnaces with 3-phase electrical supply < 225,000 Btu/hour	Mobile Home	75 AFUE
	All others	78 AFUE or 80 Thermal Efficiency (at manufacturer's option)

TABLE E-9
STANDARDS FOR DUCT FURNACES

Appliance	*Fuel*	*Standards*		
		Minimum Thermal Efficiency %[1]		*Maximum Energy Consumption during standby (watts)*
		At maximum rated capacity	*At minimum rated capacity*	
Duct furnaces	Natural gas	80	75	10
Duct furnaces	LPG[2]	80	75	147

[1] As provided and allowed by the controls.
[2] Designed expressly for use with LPG.

TABLE F-4
STANDARDS FOR SMALL WATER HEATERS THAT ARE NOT FEDERALLY REGULATED CONSUMER PRODUCTS

Appliance	*Energy Source*	*Input Rating*	*Rated Storage Volume (gallons)*	*Minimum Energy Factor*[1]
Storage water heaters	Gas	≤ 75,000 Btu/hr	< 20	0.62 – (.0019 x V)
Storage water heaters	Gas	≤ 75,000 Btu/hr	> 100	0.62 – (.0019 x V)
Storage water heaters	Oil	≤ 105,000 Btu/hr	> 50	0.59 – (.0019 x V)
Storage water heaters	Electricity	≤ 12 kW	> 120	0.93 – (.00132 x V)
Instantaneous Water Heaters	Gas	≤ 50,000 Btu/hr	Any	0.62 – (.0019 x V)
Instantaneous Water Heaters	Gas	≤ 200,000 Btu/hr	≥ 2	0.62 – (.0019 x V)
Instantaneous Water Heaters	Oil	≤ 210,000 Btu/hr	Any	0.59 – (.0019 x V)
Instantaneous Water Heaters	Electricity	≤ 12 kW	Any	0.93 – (.00132 x V)

[1] Volume (V) = rated storage volume in gallons.

TABLE H-2
STANDARDS FOR TUB SPOUT DIVERTERS

Appliance	*Testing Conditions*	*Maximum Leakage Rate*
Tub spout diverters	When new	0.01 gpm
	After 15,000 cycles of diverting	0.05 gpm

TABLE K-9
STANDARDS FOR STATE-REGULATED INCANDESCENT REFLECTOR LAMPS

Rated Lamp Wattage	Minimum Average Lamp Efficacy (LPW)
40-50	10.5
51-66	11.0
67-85	12.5
86-115	14.0
116-155	14.5
156-205	15.0

TABLE K-10
STANDARDS FOR STATE-REGULATED GENERAL SERVICE INCANDESCENT LAMPS -TIER I

Rated Lumen Ranges	*Maximum Rated Wattage*	*Minimum Rated Lifetime*	*Effective Date*
1490-2600 Lumens	72 watts	1,000 Hours	Jan 1, 2011
1050-1489 Lumens	53 watts	1,000 Hours	Jan 1, 2012
750-1049 Lumens	43 watts	1,000 Hours	Jan 1, 2013
310-749 Lumens	29 watts	1,000 Hours	Jan 1, 2013

TABLE K-11
STANDARDS FOR STATE-REGULATED GENERAL SERVICE LAMPS -TIER II

Lumen Ranges	*Minimum Lamp Efficacy*	*Minimum Rated Lifetime*	*Effective Date*
All	45 lumens per watt	1,000 Hours	Jan 1, 2018

TABLE K-12
STANDARDS FOR STATE-REGULATED MODIFIED SPECTRUM GENERAL SERVICE INCANDESCENT LAMPS -TIER I

Rated Lumen Ranges	*Maximum Rated Wattage*	*Minimum Rated Lifetime*	*Effective Date*
1118-1950 Lumens	72 watts	1,000 Hours	Jan 1, 2011
788-1117 Lumens	53 watts	1,000 Hours	Jan 1, 2012
563-787 Lumens	43 watts	1,000 Hours	Jan 1, 2013
232-562 Lumens	29 watts	1,000 Hours	Jan 1, 2013

TABLE L-1
ULTRASOUND MAXIMUM DECIBEL VALUES

Mid-frequency of Sound Pressure Third-Octave Band (in kHz)	*Maximum db Level within third-Octave Band (in dB reference 20 micropascals)*
Less than 20	80
20 or more to less than 25	105
25 or more to less than 31.5	110
31.5 or more	115

TABLE M-2
STANDARDS FOR TRAFFIC SIGNAL MODULES FOR PEDESTRIAN CONTROL SOLD OR OFFERED FOR SALE IN CALIFORNIA

Type	*at 25°C (77°F)*	*At 74°C (165.2°F)*
Hand or 'Don't Walk' sign or countdown.	10 watts	12 watts
Walking Person or 'Walk' sign	9 watts	12 watts

TABLE N-1
STANDARDS FOR UNDER-CABINET LUMINAIRES

Lamp Length (inches)	*Minimum Ballast Efficacy Factor (BEF) for one lamp*	*Minimum Ballast Efficacy Factor (BEF) for two lamps*
≤29	4.70	2.80
>29 and ≤35	3.95	2.30
>35 and ≤41	3.40	1.90
>41 and ≤47	3.05	1.65
>47	2.80	1.45

TABLE N-2
MINIMUM REQUIREMENTS FOR PORTABLE LED LUMINAIRES, AND PORTABLE LUMINAIRES WITH LED LIGHT ENGINES WITH INTEGRAL HEAT SINK

Criteria	*Requirement*
Light Output	≥ 200 lumens (initial)
Minimum LED Luminaire Efficacy	29 lumens/W
Minimum LED Light Engine Efficacy	40 lumens/W
Color Correlated Temperature (CCT)	2700 K through 5000 K
Minimum Color Rendering Index (CRI)	75
Power Factor (for luminaires labeled or sold for residential use)	≥ 0.70

TABLE U-2
STANDARDS FOR STATE-REGULATED EXTERNAL POWER SUPPLIES EFFECTIVE JANUARY 1, 2007 FOR EXTERNAL POWER SUPPLIES USED WITH LAPTOP COMPUTERS, MOBILE PHONES, PRINTERS, PRINT SERVERS, CANNERS, PERSONAL DIGITAL ASSISTANTS (PDAS), AND DIGITAL CAMERAS. EFFECTIVE JULY 1, 2007 FOR EXTERNAL POWER SUPPLIES USED WITH WIRELINE TELEPHONES AND ALL OTHER APPLICATIONS.

Nameplate Output	*Minimum Efficiency in Active Mode*
0 to < 1 watt	0.49 * Nameplate Output
≥ 1 and ≤ 49 watts	0.09 * Ln(Nameplate Output) + 0.49
> 49 watts	0.84
	Maximum Energy Consumption in No-Load Mode
0 to <10 watts	0.5 watts
≥ 10 to ≤ 250 watts	0.75 watts
Where Ln (Nameplate Output) = Natural Logarithm of the nameplate output expressed in watts.	

TABLE U-3
STANDARDS FOR STATE-REGULATED EXTERNAL POWER SUPPLIES EFFECTIVE JULY 1, 2008

Nameplate Output	*Minimum Efficiency in Active Mode*
<1 watt	0.5 * Nameplate Output
≥ 1 and ≤ 51 watts	0.09*Ln(Nameplate Output) + 0.5
> 51 watts	0.85
	Maximum Energy Consumption in No-Load Mode
Any output	0.5 watts
Where Ln (Nameplate Output) = Natural Logarithm of the nameplate output expressed in watts.	

TABLE V-1
STANDARDS FOR CONSUMER AUDIO AND VIDEO EQUIPMENT

Appliance Type	*Effective Date*	*Maximum Power Usage (Watts)*
Compact Audio Products	January 1, 2007	2 W in Audio standby-passive mode for those without a permanently illuminated clock display 4 W in Audio standby-passive mode for those with a permanently illuminated clock display
Digital Versatile Disc Players and Digital Versatile Disc Recorders	January 1, 2006	3 W in Video standby-passive mode

TABLE V-2
STANDARDS FOR TELEVISIONS

Effective Date	*Screen Size (area A in square inches)*	*Maximum TV Standby-passive Mode Power Usage (watts)*	*Maximum On Mode Power Usage (P in Watts)*	*Minimum Power Factor for (P ≥ 100W)*
January 1, 2006	All	3 W	No standard	No standard
January 1, 2011[*]	A < 1400	1 W	P ≤ 0.20 x A + 32	0.9
January 1, 2013	A < 1400	1 W	P ≤ 0.12 x A + 25	0.9

TABLE W-1
STANDARDS FOR LARGE BATTERY CHARGER SYSTEMS

Performance Parameter		*Standard*
Charge Return Factor (CRF)	100 percent, 80 percent Depth of discharge	CRF≤ 1.10
	40 percent Depth of discharge	CRF ≤ 1.15
Power Conversion Efficiency		Greater than or equal to: 89 percent
Power Factor		Greater than or equal to: 0.90
Maintenance Mode Power (E_b = battery capacity of tested battery)		Less than or equal to: 10 + 0.0012E_b W
No Battery Mode Power		Less than or equal to: 10 W

TABLE W-2
STANDARDS FOR SMALL BATTERY CHARGER SYSTEMS

Performance Parameter	***Standard***
Maximum 24-hour charge and maintenance energy (Wh) (E_b = capacity of all batteries in ports and N = number of charger ports)	For E_b of 2.5 Wh or less: $16 \times N$
	For E_b greater than 2.5 Wh and less than or equal to 100 Wh: $12 \times N + 1.6E_b$
	For E_b greater than 100 Wh and less than or equal to 1000 Wh: $22 \times N + 1.5E_b$
	For E_b greater than 1000 Wh: $36.4 \times N + 1.486E_b$
Maintenance Mode Power and No Battery Mode Power (W) (E_b = capacity of all batteries in ports and N = number of charger ports)	The sum of maintenance mode power and no battery mode power must be less than or equal to: $1 \times N + 0.0021 \times E_b$

Appendix C - California Climate Zones

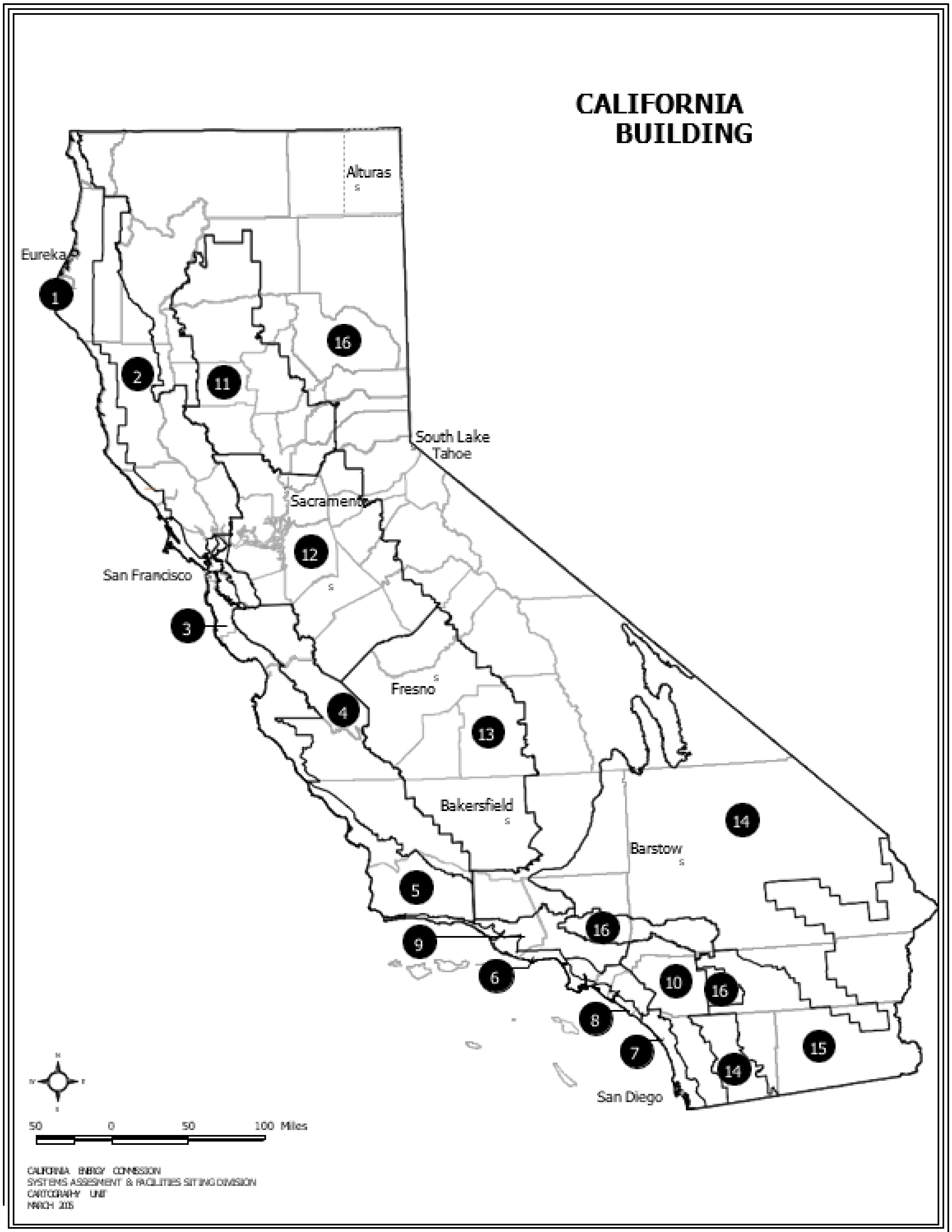
All energy calculations used for compliance with the Standards must use the climate zone applicable to a building project is determined based on its physical location as it relates to the determinations of climate regions found in the Commission publication California Climate Zone Descriptions, which contains detailed survey definitions of the 16 climate zones.

The list of climate zone areas by ZIP code is located on the CEC website here: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/climate-zone-tool-maps-and

CEC has also developed an interactive climate zone lookup tool that allow user to locate climate zone by address or ZIP code. The lookup tool is located here:

http://caenergy.maps.arcgis.com/apps/webappviewer/index.html?id=4831772c00eb4f729924167244bbca22

FIGURE 100.1-A—CALIFORNIA CLIMATE ZONES



Appendix D - Demand Responsive Controls

This appendix to the nonresidential compliance manual addresses the demand responsive (DR) control requirements in the 2022 Building Energy Efficiency Standards (Energy Standards).

Demand response is an increasingly important function of buildings as distributed energy resources become more common and customers have access to time of use electricity rates and incentive programs designed to encourage demand side optimization. Demand response occurs on a range of timescales, from seconds to seasons, and represents any demand change in response to grid or economic needs. In addition to current time of use electricity rates, utilities in the future will likely connect electricity costs to high frequency fluctuations in both the supply and demand for electricity. Appropriate demand responsive controls allow building operators to maintain the quality of services a building provides and reduce the total cost of energy by automating a building's response to changes in electricity rates.

The following definitions from §100.1 are relevant to the DR control requirements:

> **Demand Response** is short-term changes in electricity usage by end-use customers, from their normal consumption patterns. Demand response may be in response to:
>
> a. Changes in the price of electricity; or
> b. Participation in programs or services designed to modify electricity use.
>   i. In response to wholesale market prices.
>   ii. When system reliability is jeopardized.
>
> **Demand Response Period** is a period of time during which electricity loads are modified in response to a demand response signal.
>
> **Demand Response Signal** is a signal that indicates a price or a request to modify electricity consumption for a limited time period.
>
> **Demand Responsive Control** is an automatic control that is capable of receiving and automatically responding to a demand response signal.

The DR control requirements ensure that the building is DR capable (i.e., capable of responding to a DR signal). The decision to employ demand response is up to the building owner or manager, in coordination with their utility company and/or a governing authority. A building that is capable of receiving and responding to a demand response signal is sufficient to meet the requirements of the Energy Standards. DR-capable is described as follows:

> **DR-capable:** A building is *capable* of DR when the building has loads that can be managed, DR controls are installed, and the DR controls have been programed/configured so the test control strategy that is defined in the building code can be deployed (note: the DR controls may be programmed with additional control strategies).

Table D-1 summarizes when DR controls are required in nonresidential buildings.

The requirements for DR controls only apply if the controls are used to comply with the building standards (i.e., DR lighting controls, zonal HVAC controls, receptacle controls, or electronic message center control). If DR controls are installed voluntarily without any code requirements, then they do not need to adhere to the demand responsive controls requirements in Title 24, Part 6.

Table D-1: Summary of DR Control Requirements for Nonresidential Buildings

System	Application	Required DR Controls	Response Tested for Title 24 Compliance	Acceptance Test

HVAC	Direct Digital Control (DDC) to the Zone level[1]	Must have DR Controls that are compliant with §110.12(a) and (b)	• During DR Period, in non-critical zones:
			  ○ In cooling mode, increase the operating cooling temperature 4°F or more
			  ○ In heating mode, decrease the operating heating temperature 4°F or more
			• Upon conclusion of the DR Period, reset the temperature set points to their original settings.
			• Provide an adjustable rate of change for the temperature.
				NA7.5.10: Automatic Demand Shed Control Acceptance

HVAC	Single-zone air conditioner and heat pump system (without DDC to the Zone Level)[1,2]	Must have thermostatic controls that are compliant with Joint Appendix 5.	Defined in Joint Appendix 5.	Not applicable
Lighting	Nonresidential lighting systems subject to §130.1(b) with an installed lighting power[3] of 4,000 watts or greater, and lighting claiming the demand responsive lighting PAF	Must have DR controls that are compliant with §110.12(a) and (c)	Reduce total installed lighting power by a minimum of 15 percent below the design full output level for the duration of the Demand Response Period. Total installed lighting includes general lighting systems subject to §130.1(b) and additional lighting systems in the space. [3,] If only general lighting power is reduced in the space, then the general lighting power may need to be reduced by more than 15 percent depending on the amount of additional lighting power in the space.	NA7.6.3 Demand Responsive Controls Acceptance
Sign Lighting	Electronic Message Centers (EMCs) having a new connected lighting power load greater than 15 kW[4]	Must have DR controls that are compliant with §110.12(a) and (d)	Reduce lighting power by a minimum of 30 percent for the duration of the Demand Response Period. [4]	Not applicable

Electrical Power Systems	Controlled receptacles that meet §130.5(d) and where demand responsive lighting controls are required for the building or space.	Must have DR controls that are compliant with §110.12(a) and (e)	Automatically turn off all connected loads for the duration of the Demand Response Period. [5]	NA7.6.5
Electrical Power System	Circuit-level controls installed as part of the electrical power distribution system[6]	Must have DR controls that are compliant with §110.12(a)	Not applicable	Not applicable

1. Systems serving exempt process loads that must have constant temperatures to prevent degradation of materials, a process, plants, or animals are exempt.
2. Package terminal air conditioners, package terminal heat pumps, room air conditioners, and room air-conditioner heat pumps are exempt.
3. Lighting systems not subject to §130.1(b) and spaces in which lighting power or illuminance is not permitted to be reduced in accordance with health or life safety statues, ordinances, or regulations are not required to be capable of automatically reducing lighting power when a DR Signal is received.
4. Lighting for EMCs where lighting power or illuminance is not permitted to be reduced by 30 percent in accordance with a health or life safety statute, ordinance, or regulation is exempt.
5. Buildings not required to have demand responsive lighting controls and spaces where a health or life safety statue, ordinance, or regulation does not permit the receptacles to be automatically controlled are exempt.

Circuit-level controls installed to control HVAC, lighting, or sign lighting equipment must comply with the requirements for that application.

1. Communications Requirements for DR Controls

§110.12(a)1-5

There are two main communication requirements that apply to all DR controls:

1. The control must, at minimum, be installed with an OpenADR 2.0a or 2.0b certified virtual end node (VEN), or be on the Energy Commission's list of certified demand responsive controls; and
2. The control must, at a minimum, be able to communicate with the virtual end node using a wired or wireless bi-directional communication pathway.

These are minimum requirements, meaning that the control may have (and use) additional communication features provided that the required minimum features are included.

1.1 Communication with Entity that Initiates DR Signal

§110.12(a)1

The DR control system must have the capability of communicating with the entity that initiates a DR signal by way of an OpenADR certified virtual end node (VEN).

The OpenADR 2.0 protocol is the primary open-standard protocol used in the California market. It implements a profile within the Organization of Structured Information Standards (OASIS) Energy Interoperation information and communication model that defines two types of communications entities – virtual top nodes (VTNs) and virtual end nodes (VENs). VTNs are either physical or cloud based information exchange servers, typically operated by utilities or third-party providers, that transmit events or price information. VENs are the hardware that receive the data transmitted by a VTN, and are typically the gateway or end-use devices installed at customer facilities. See OpenADR Alliance's website (http://www.openadr.org/) for more information about OpenADR certified VENs.[1]

There are two ways to comply with the OpenADR certified VEN requirement:

Option A: Install an OpenADR 2.0a or 2.0b certified VEN physically within the building as part of the DR control system (§110.12(a)1A)

If complying using Option A (§110.12(a)1A), the designer of the DR control system(s) must meet two requirements:

[1] The OpenADR Alliance's Frequently Asked Questions webpage is a helpful resource: http://www.openadr.org/faq.

1. Select an OpenADR Alliance Certified VEN, compliant with the OpenADR 2.0a or 2.0b specification.[2] The OpenADR Alliance maintains a list of certified VENs (https://products.openadr.org/).
2. The certified VEN must be installed inside the building at the time of inspection. The building can comply if the DR control system has a certified VEN that is incorporated into a networked system of devices such that the VEN communicates with multiple devices in the network (e.g., a gateway system). Alternately, each demand responsive control device in the building could itself be a certified VEN.

Option B: Install a DR control system that has been certified to the Energy Commission as being capable of communicating with an OpenADR 2.0b certified VEN (§110.12(a)1B)

If complying using Option B (§110.12(a)1B), the designer of the DR control system(s) must meet three requirements:

1. Select a DR control system that the Energy Commission has approved for the certified list of demand responsive controls. The Energy Commission maintains a list of certified products and instructions on how manufacturers can certify products on their website: http://www.energy.ca.gov/title24/equipment_cert/.
2. The VEN may be separately located on-site, offsite or in the cloud, and is not required to be in operation at the time of permitting.
3. The demand responsive controls must still be programed or configured so any test control strategy defined in the building code can be deployed at the time of permitting.
4. The manufacturer of the DR control system must certify to the Energy Commission that the control system is capable of communicating with an OpenADR 2.0b certified VEN. This requirement does not mean that the DR control system must be connected to a 2.0b certified VEN. When the DR control system is connected to a VEN, it can be connected to either a 2.0a or 2.0b certified VEN.

The DR control system must comply with Option A or Option B, but the control system can also include features that allow the control system to use other communications protocols.

When specifying DR control systems, it is recommended that the controls designer check to see which DR programs are currently available in the area and specify controls that are both compliant with Title 24, Part 6 and eligible for the area's DR programs.

[2] The OpenADR 2.0a and 2.0b specifications are available on the OpenADR Alliance's website: http://www.openadr.org/specification.

2. Other Requirements for DR Controls

2.1 Perform Regular Functions When Not Responding to DR Events

§110.12(a)4

Controls that include demand response with other control functions must perform their regular control functions, as required by other parts of the building code, when the control is not performing DR-related functions. This includes when the controls are not responding to a DR event, when the DR functions are not enabled (see description of DR-enabled in the introduction to this chapter of the compliance manual) or when the DR controls are temporarily disabled or disconnected (e.g., due to a network outage).

For example, if the building owner/operator never enables the DR controls or enrolls in a DR program, the building control system(s) must comply with all other applicable controls requirements and continue to provide those control functions. Similarly, if the building owner/operator does enable the DR controls and is enrolled in a DR program, the building control system(s) must perform as required by the applicable building code requirements whenever the building is not participating in a DR event. The DR control functionality is an additional control feature on top of all of the other required building controls.

2.2 Certification Requirements for DR Thermostats

§110.12(a)5

DR thermostats must comply with the technical specifications described in Joint Appendix 5 (JA5). According to the requirement in JA5, manufacturers of DR thermostats must submit documentation to the Energy Commission to certify that the thermostat meets the code requirements. See the Energy Commission's website for a list of certified products and for instructions to manufacturers that wish to certify products: http://www.energy.ca.gov/title24/equipment_cert/.

3. DR Controls for HVAC Systems

3.1 HVAC Systems with DDC to the Zone Level

§110.12(b)

As specified in §120.2(j), the Energy Standards require certain buildings to have Direct Digital Control (DDC) to the zone level (See Chapter 4 Section 4.5.1.9 of the nonresidential compliance manual). When the building has DDC to the zone level, either to comply with the Energy Standards or if DDC was installed voluntarily, the HVAC system must also have a DR control system that complies with the requirements in §110.12(a) and (b).

At the time of inspection, the DR control system must be programmed so it automatically initiates the test control strategy described below. The DR control system must pass this test to comply with code, regardless of what control strategy the building operator intends to use. If a building owner/operator enables the DR controls and enrolls in a DR program (see description of these terms in the introduction to this chapter), they have the option of deploying alternate control strategies consistent with their program. The strategy described in the Energy Standards is simply a test to confirm the DR control system is installed correctly and can perform its function, while also being suitable for leaving in place after testing.

Test control strategy:

When the person performing the acceptance test manually simulates the condition where the HVAC control system receives a DR signal and a DR Period is beginning, the HVAC system must initiate the following response:

1. When in cooling mode, increase the operating cooling temperature set points by 4°F or more in all non-critical zones and maintain the set points throughout the DR Period.
2. When in heating mode, decrease the operating heating temperature set points by 4°F or more in all non-critical zones and maintain the set points throughout the DR Period.
3. Maintain the temperature and ventilation set points in all critical zones throughout the DR Period.

When the person performing the acceptance test manually simulates a condition where the DR Period has concluded, the control system must restore the temperature set points in non-critical zones to the settings that were in place before the DR Period began.

In addition, the controls must be able to provide an adjustable rate of temperature change when the temperature is adjusted at the beginning and the end of the DR Period.

The control strategy calls for adjustments to temperature setpoints in non-critical zones while maintaining setpoints in critical zones. The Energy Standards define a critical zone as "a zone serving a process where reset of the zone temperature setpoint during a demand shed event might disrupt the process, including but not limited to computer rooms, data centers, telecom and private branch exchange (PBX) rooms, and laboratories." Non-critical zones are defined as "a zone that is not a critical zone."

(Note that the connection between the entity that initiates the DR signal and the control system within the building is not evaluated as part of the test.)

In addition to demonstrating compliance with the test condition, the DR controls for HVAC systems with DDC to the zone level must allow an authorized facilities operator to: 1) disable the DR controls, and 2) manually adjust heating and cooling setpoints from a centralized location on either the HVAC control system or the building's energy management control system.

An acceptance test is necessary to ensure that the system was programmed as required. See Nonresidential Appendix 7.5.10 and Chapter 13 of this compliance manual for more information on the acceptance test requirements.

3.2 HVAC Systems without DDC to the Zone Level

§120.2(b)4

In buildings that do not have DDC to the zone level, thermostatic controls for single zone air conditioners and heat pumps must be DR thermostats, also called Occupant Controlled Smart Thermostats (OCSTs). There are two exceptions to this requirement:

1. Systems serving zones that must have constant temperatures to protect a process or product (e.g., a laser laboratory or a museum).
2. The following HVAC systems:
    a. Gravity gas wall heaters
    b. Gravity floor heaters
    c. Gravity room heaters
    d. Non-central electric heaters
    e. Fireplaces or decorative gas appliance
    f. Wood stoves
    g. Room air conditioners
    h. Room heat pumps
    i. Packaged terminal air conditioners
    j. Packaged terminal heat pumps

When OCSTs are required, they must comply with the technical specifications described in Joint Appendix 5 (JA5). According the requirement in JA5, manufacturers of OCSTs must submit documentation to the Energy Commission to certify that the thermostat meets the code requirements. See the Energy Commission's website for a list of certified products and for instructions to manufacturers that wish to certify products: http://www.energy.ca.gov/title24/equipment_cert/.

4. DR Controls for Lighting Systems

§110.12(c)

Nonresidential indoor lighting systems subject to §130.1(b) with an installed lighting power of 4,000 watts or greater must be equipped with DR controls that comply with §110.12(a) and (c). There are two exceptions that impact the calculation of the 4,000 watt threshold and impact where DR controls must be installed. Specifically, spaces that fall into these two categories do not need to have DR lighting controls and do not need to be included in the calculation of the 4,000 watt threshold:

1. Lighting systems not subject to §130.1(b); and
2. Spaces where health or life safety statute, ordinance, or regulation does not permit lighting to be reduced.

At the time of inspection, the DR control system must be programmed to automatically initiate the test control strategy described below. The DR control must pass this test to comply with code regardless of what control strategy the building operator intends to use. If a building owner/operator enables the DR controls and enrolls in a DR program (see description of these terms in the introduction to this chapter), they have the option of deploying alternate control strategies consistent with their program. There is no acceptance test to verify such alternate control strategies. The strategy described in the Energy Standards is simply a test for confirming the DR control system is installed correctly and can perform its function, while also being suitable for leaving in place after testing.

Test control strategy

When the acceptance test technician manually simulates the condition where the lighting control system receives a DR signal, the lighting system must automatically reduce lighting power so that the total installed lighting power of building or space, excluding lighting where health and safety statute, ordinance or regulation do not permit lighting to be reduced, is reduced by a minimum of 15 percent below the total installed lighting power. This means that lighting power for general lighting systems subject to §130.1(b) must be reduced by more than 15 percent to account for no reduction in the additional lighting systems, or a combination of reduction in the power of general lighting systems subject to §130.1(b) and additional lighting systems must be reduced to achieve at least a 15 percent reduction in total lighting power across these lighting systems. Lighting subject to §130.1(b) shall be reduced in a manner consistent with uniform level of illumination requirements in Table 5-1 in Chapter 5 of this compliance manual (Table 130.1-A of the Energy Standards).

(Note that the connection between the entity that initiates the DR signal and the control system within the building is not evaluated as part of the test.)

An acceptance test is necessary to ensure that the system is installed correctly and includes a basic, functional level of programming. See Nonresidential Appendix NA7.6.3 and Chapter 14 of this compliance manual for more information on the acceptance testing requirements.

Example 4-1 Compliance Method 1 – Using Centralized Powerline Dimming Control

This method requires the use of luminaires with dimmable ballasts or LED drivers, compatible with powerline controls, and the use of a lighting control panel downstream of the breaker panel. The lighting circuit relays are replaced by circuit controllers, which can send the dimming signal via line voltage wires. The panel could have several dry contact inputs that provide dedicated levels of load shed depending upon the DR signal received. Different channels can be assigned to have different levels of dimming as part of the demand response. Local controls can be provided by either line voltage or low voltage controls.

Example 4-2 Compliance Method 2 – Using Addressable Lighting System

The addressable lighting system is similar in design to that of a centralized control panel, but with additional granularity of control. With an addressable system, each fixture can be addressed individually, whereas a centralized control panel is limited to an entire channel, or circuit, being controlled in unison. The cost of enabling DR on a system with a centralized control panel is less dependent on building size or number of rooms than an addressable zone based system.

Enabling DR for the addressable lighting system entails making a dry contact input available to receive an electronic signal. This is a feature that is included in the base model of most lighting control panels. Some smaller scale addressable lighting systems may have a limited number of inputs dedicated for alternative uses, such as a time clock. If this is the case, an I/O input device can be added to the network to provide an additional closed contact input.

Example 4-3 Compliance Method 3 – Demand Response for Select Zones

Enabling demand response for a zoned system would entail adding a network adapter to each room to be controlled for purposes of demand response. The network adapter allows for each room to be monitored and controlled by an energy management control system (EMCS). These types of systems are commonly used for HVAC systems, and to respond to demand response signals. The assumption is that if the building is installing an EMCS, the preference would be to add the lighting network to that existing demand response system. There is additional functionality that results from adding the lighting system to an EMCS. In addition to being able to control the lighting for demand response, the status of the lighting system can then be monitored by the EMCS. For example, occupancy sensors would be able to be used as triggers for the HVAC system, turning A/C on and off when people entered and leave the room. Therefore, the potential for savings from this type of system is higher than the value of the lighting load shed for demand response.

5. DR Controls for Electronic Message Centers

§110.12(d)

An electronic message center (EMC) is a pixilated image producing electronically controlled sign formed by any light source. EMCs that have a lighting load greater than 15kW must have demand responsive controls unless a health or life safety statute, ordinance, or regulation does not permit EMC lighting to be reduced. The DR controls must meet the requirements in §110.12(a) (as explained in Section 1 above) and be capable of reducing the lighting power by a minimum of 30 percent during a DR Period.

7. DR Controls for Controlled Receptacles

§110.12(e)

Controlled receptacles are required by §130.5(d) and §160.6(d) in nonresidential buildings, hotel/motel buildings, and multifamily common service areas. Spaces required to have controlled receptacles include office areas, lobbies, conference rooms, kitchen areas in office spaces, copy rooms.

If DR lighting controls are required in the building or space per §130.1(e) or §160.5(b)4E, DR controls are also required for controlled receptacles. The DR control must be capable of automatically turning off all loads connected to the receptacle in response to a demand response signal.

8. DR Controls for Power Distribution Systems

§130.5(e)

If DR controls are installed as part of the power distribution system (e.g., circuit-level controls), the controls must meet the requirements in §110.12(a) (as explained in Section 1 above).

DR controls for HVAC, lighting, or sign lighting equipment may be installed at the circuit level; in this case, the DR controls must meet the complete requirements for that application.

9. Energy Management Control Systems (EMCS) / Home Automation Systems

Required thermostatic and lighting control functions (including DR control functions) can be incorporated into and performed by an Energy Management Control System. Using an EMCS to perform these control functions complies with Title 24 provided that all of the criteria that would apply to the control are met by the EMCS.

A Home Automation Systems that manages energy loads (such as HVAC and lighting systems) is considered a type of Energy Management Control System and, as such, can similarly incorporate the ability to provide required control functions.