

We will be starting soon!

Thanks for joining us



Duct Leakage Testing: Basics & Beyond



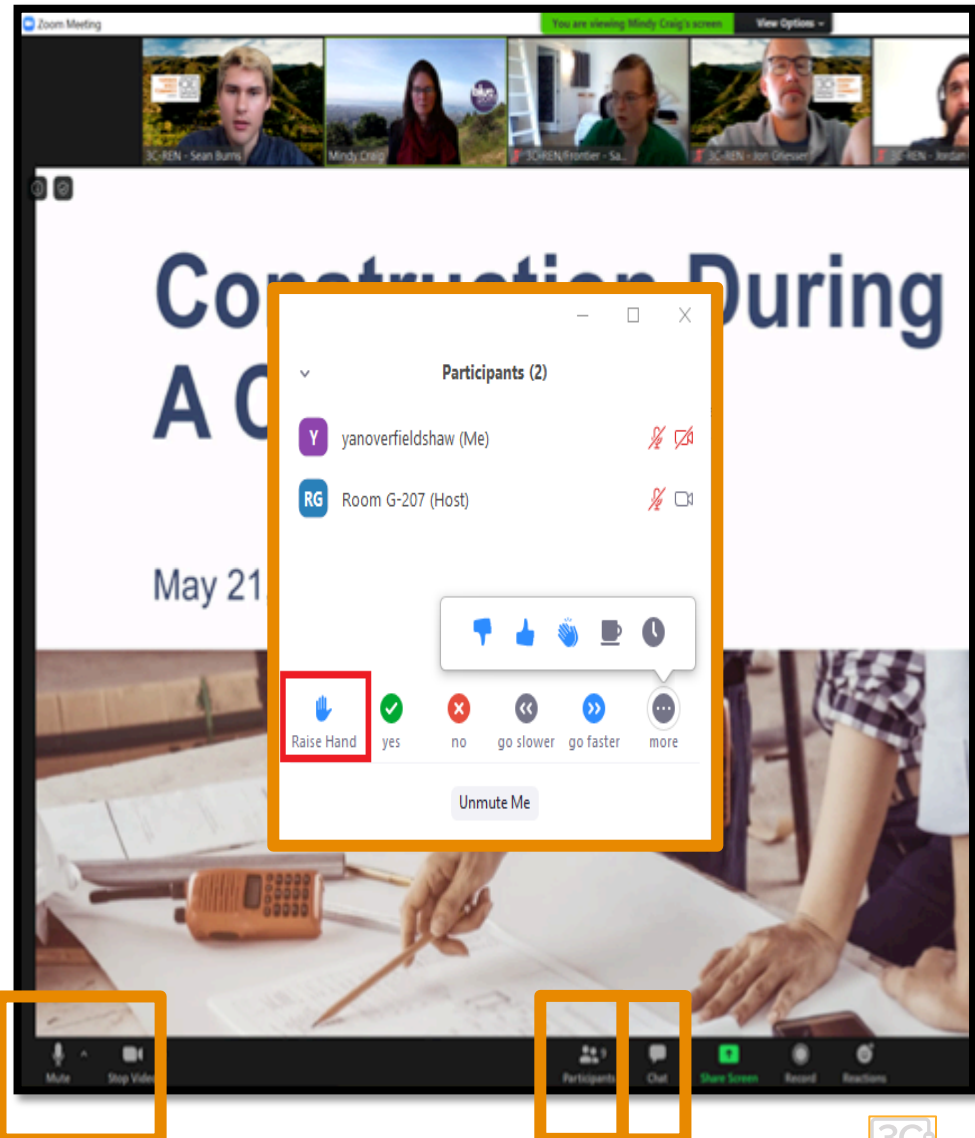
Judy Rachel – Home Performance Pro

August 23, 2022



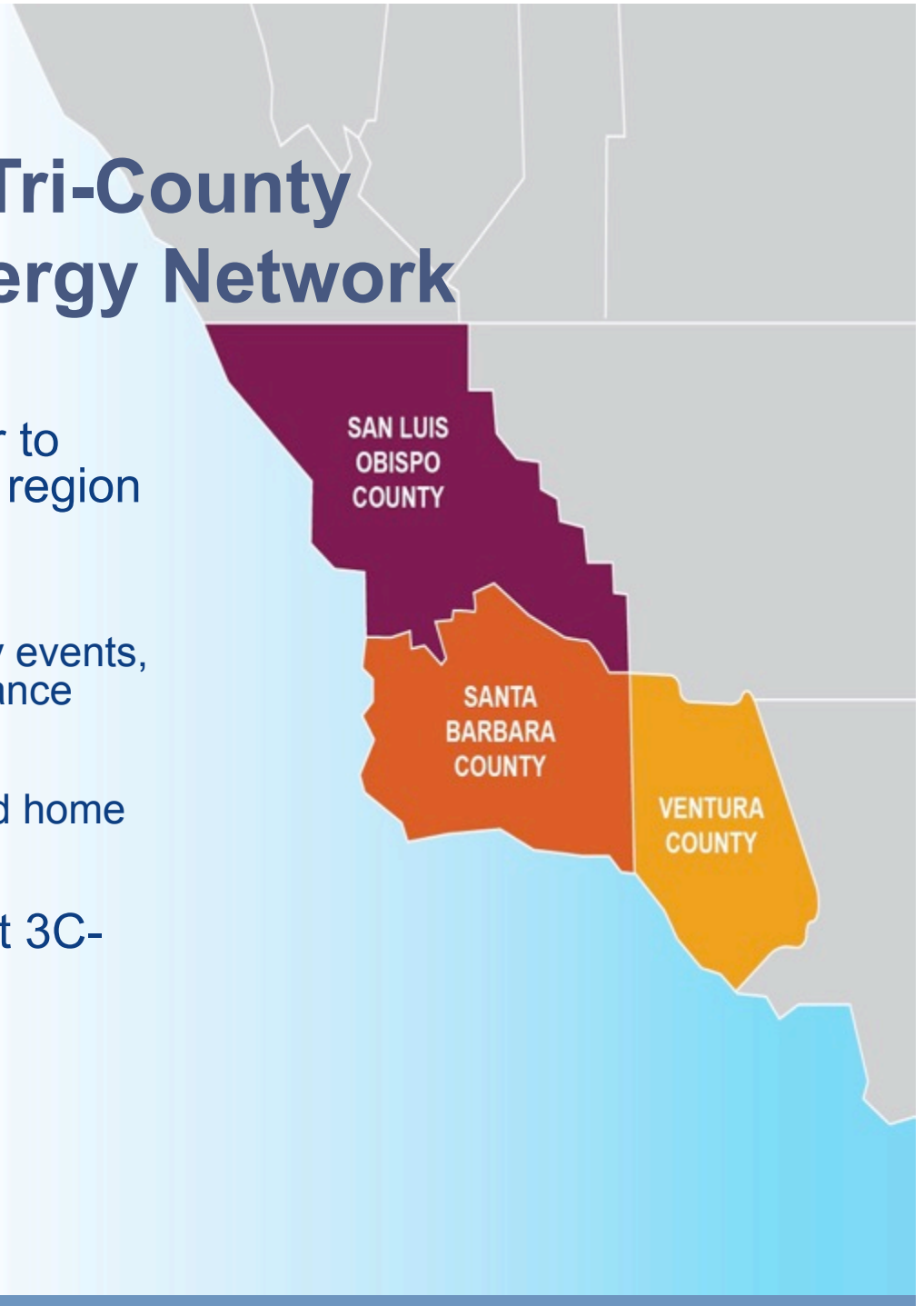
Zoom Orientation

- Please be sure your full name is displayed
- Please **mute** upon joining
- Use "**Chat**" box to share questions or comments
- Under "**Participant**" select "**Raise Hand**" to share a question or comment verbally
- The session may be **recorded** and posted to 3C-REN's on-demand page. Feel free to ask questions via the chat and keep video off if you want to remain anonymous in the recording.



3C-REN: Tri-County Regional Energy Network

- Three counties working together to improve energy efficiency in the region
- Services for –
 - **Building Professionals:** industry events, training, and energy code compliance support
 - **Households:** free and discounted home upgrades
- Funded by ratepayer dollars that 3C-REN returns to the region





ENERGY
CODE
CONNECT



BUILDING
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HOME
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3C-REN Staff Online

Need help or have
questions about 3C-
REN?

Send us a message!



More Information

- **1.5 AIA LU's Available**
 - Contact spburns@countyofsb.org for any questions regarding LUs
- **Coming to Your Inbox Soon!**
 - Slides, Recording, & Survey – Please Take It and Help Us Out!
- **Upcoming Courses**
 - 8/30 -
Stay Cool This Summer with Higher-Performing Air Conditioning: Local residents share their experiences with heat pumps for space heating and cooling
 - 8/31 – The Value of Becoming a Certified Energy Analyst (CEA)
 - 9/7 – Residential CEA Exam Prep Workshop
 - 9/8 - Nonresidential CEA Exam Preparation Workshop
 - 9/13 -
Heat Pump Fundamentals: Space Conditioning and Water Heating



Thank you!

For more info:
3c-ren.org

For questions:
info@3c-ren.org

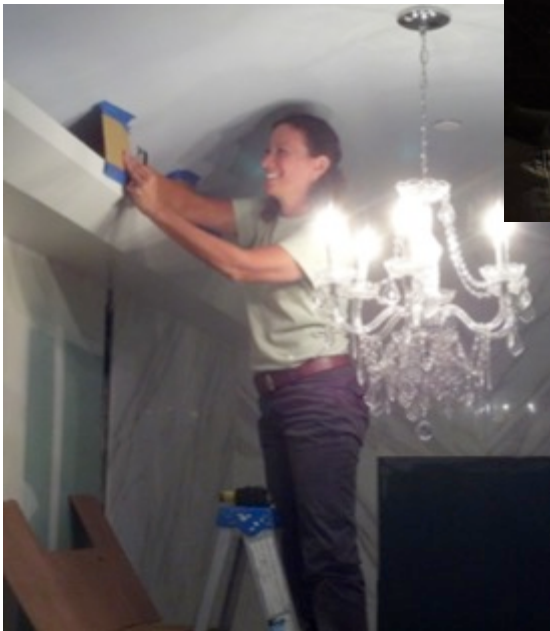


TRI-COUNTY REGIONAL ENERGY NETWORK
SAN LUIS OBISPO • SANTA BARBARA • VENTURA

Duct Leakage Testing

Basics and Beyond





Duct Testing & Beyond

- Role of the duct system*
- Significance of duct leakage
- The principles of duct testing
- Total duct leakage test
- Duct testing best practices
- Half Nelson test
- Duct leakage to the outside test
- Finding duct leaks
- Total system air flow

The Duct System

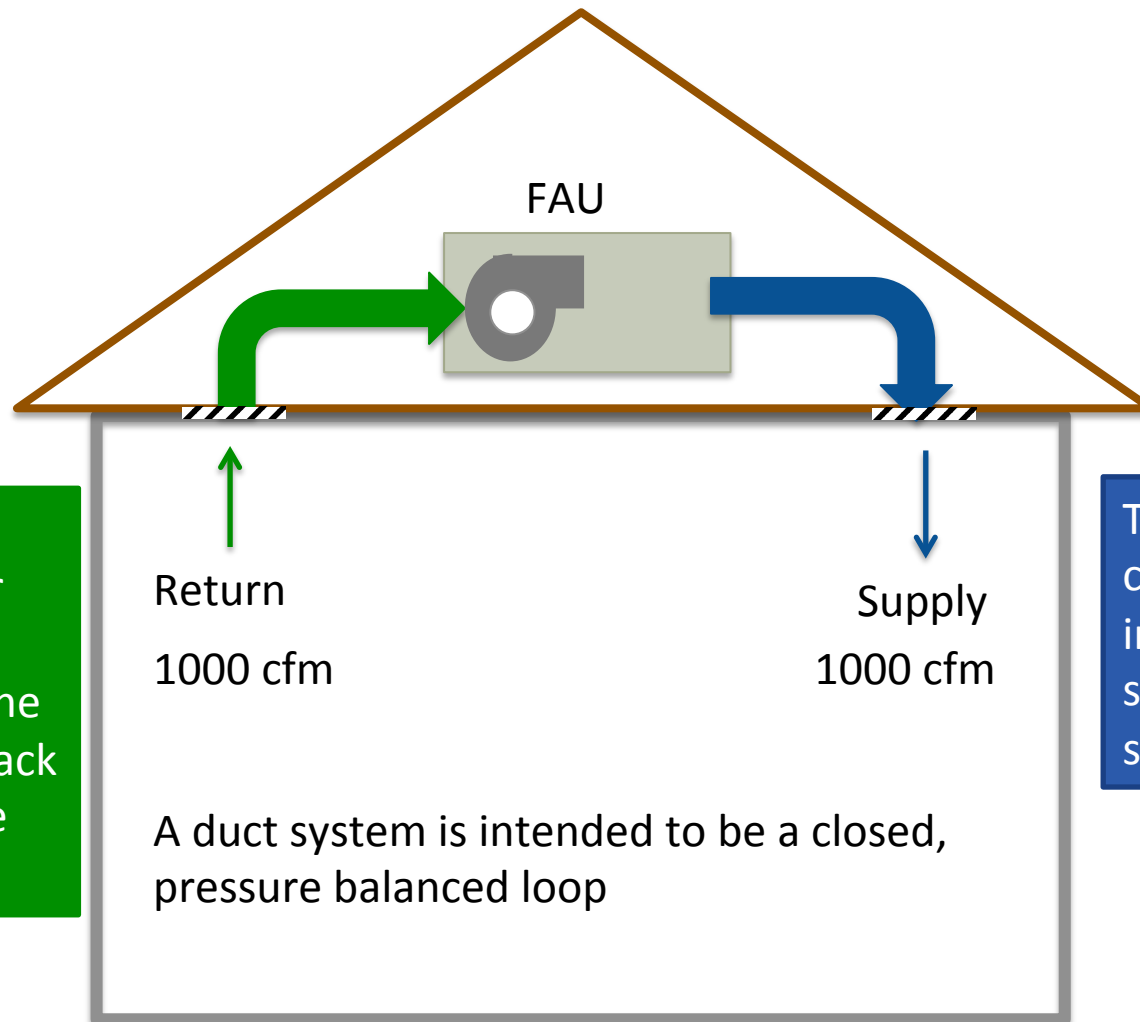
An air distribution system which conveys air to the conditioning equipment, to be conditioned, to then deliver that air to the areas of the building needing direct conditioning.

A closed, pressure balanced loop with the same amount of air entering the conditioned zones as leaving the conditioned zones.

An extension of the living space often running through areas that are outside of the living space.

When there are leaks in the ducts the pressure balance is disrupted. Zones will be pressurized or depressurized depending upon where the leaks occur.

Returns and Supplies



The FAU (forced air unit) pulls air from the living space through the return duct(s) back to the FAU to be conditioned.

The FAU blows the conditioned air into the living space via the supply ducts

A duct system is intended to be a closed, pressure balanced loop

Registers vs Grilles

Register



A combination grille and damper device

Single Deflection Adjustable Blade Diffuser Grille



Grille – a louvered or perforated face covering an opening

Diffuser – An outlet designed to distribute air in varying directions

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Importance of System Air Flow

Air is the medium being used to deliver conditioning aka capacity

System capacity should match the heating and cooling loads on the building

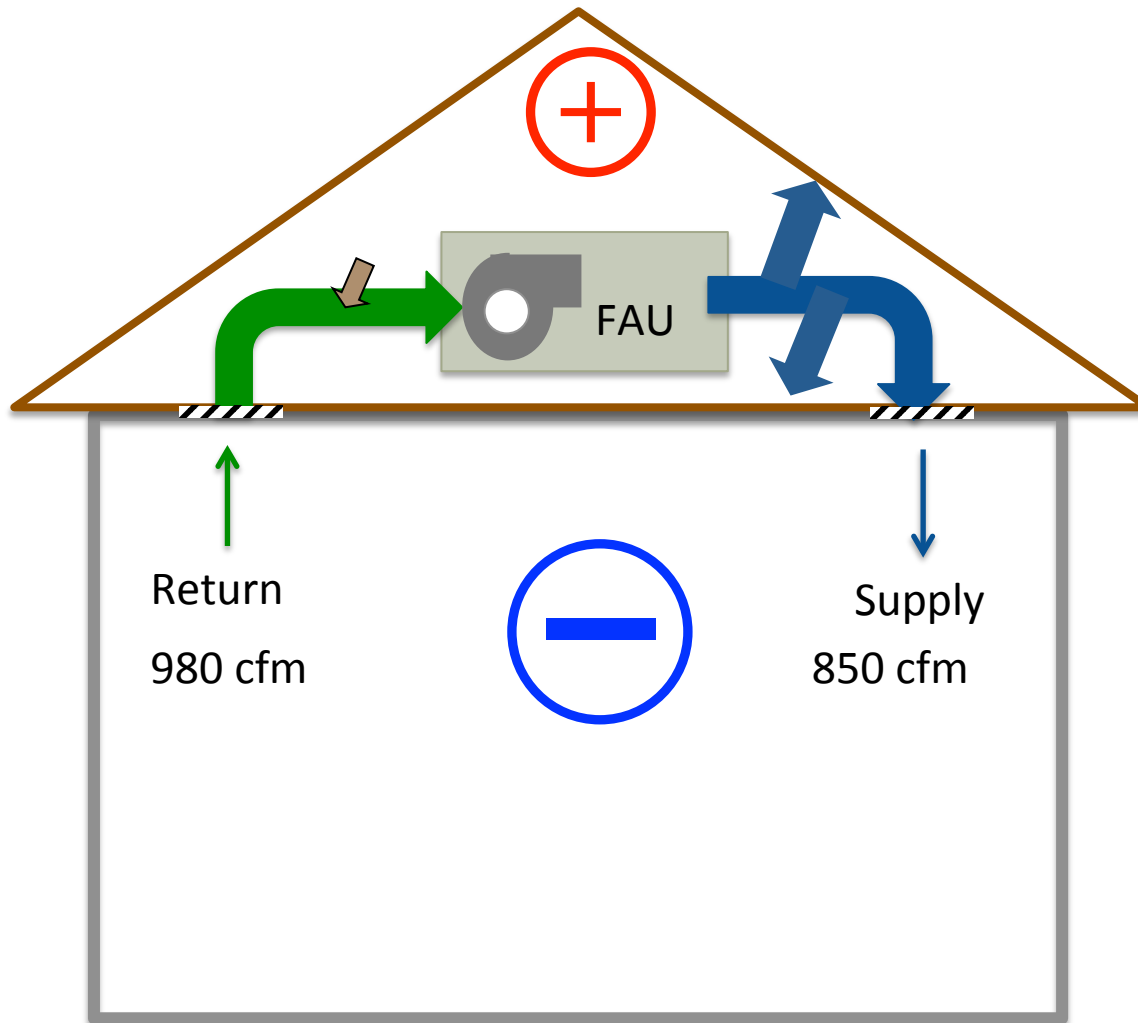
- Low air flow can lead to:
 - decreased heating and cooling system capacity
 - increased energy use
 - comfort problems
 - ice forming on the evaporator coil
 - excessive dehumidification
 - high temperature rise in heating

Three Main Effects of Duct Leakage

1. A supply leak is a direct loss of capacity
2. A return leak can bring in superheated attic air in the summer and cold air in the winter
3. The difference between supply leakage and return leakage will cause increased building infiltration

Note: While it is tempting to treat duct leakage as additional infiltration, the effect is actually more complex.

Dominant Supply Leaks

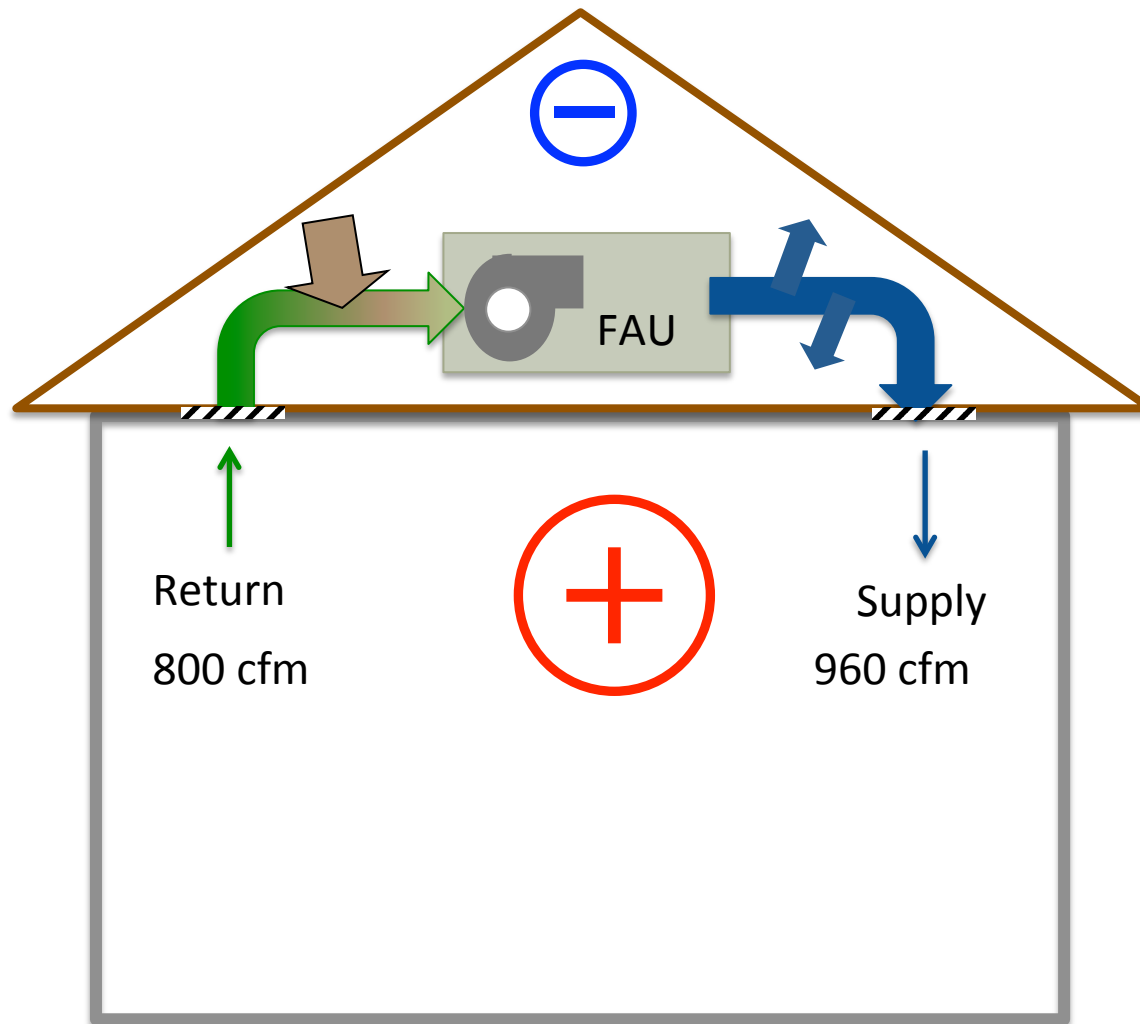


Supply leaks cause conditioned air to be dumped into attics, crawlspaces or garages instead of being delivered into the house

Negative pressures can cause:

- Combustion appliance spillage, backdrafting and flame roll-out
- Fireplace smoke to be pulled into the house
- Inward migration of soil gasses such as radon and methane, herbicides and pesticides

Dominant Return Leaks



Return leaks pull pollutants and irritants such as mold, insulation fibers, pollen and dust directly in the home.

Pulling outside air into the duct system forces the system to run longer in a less efficient manner. Both efficiency and capacity are diminished.

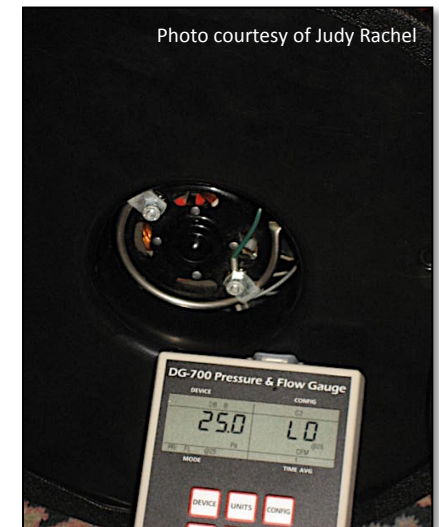
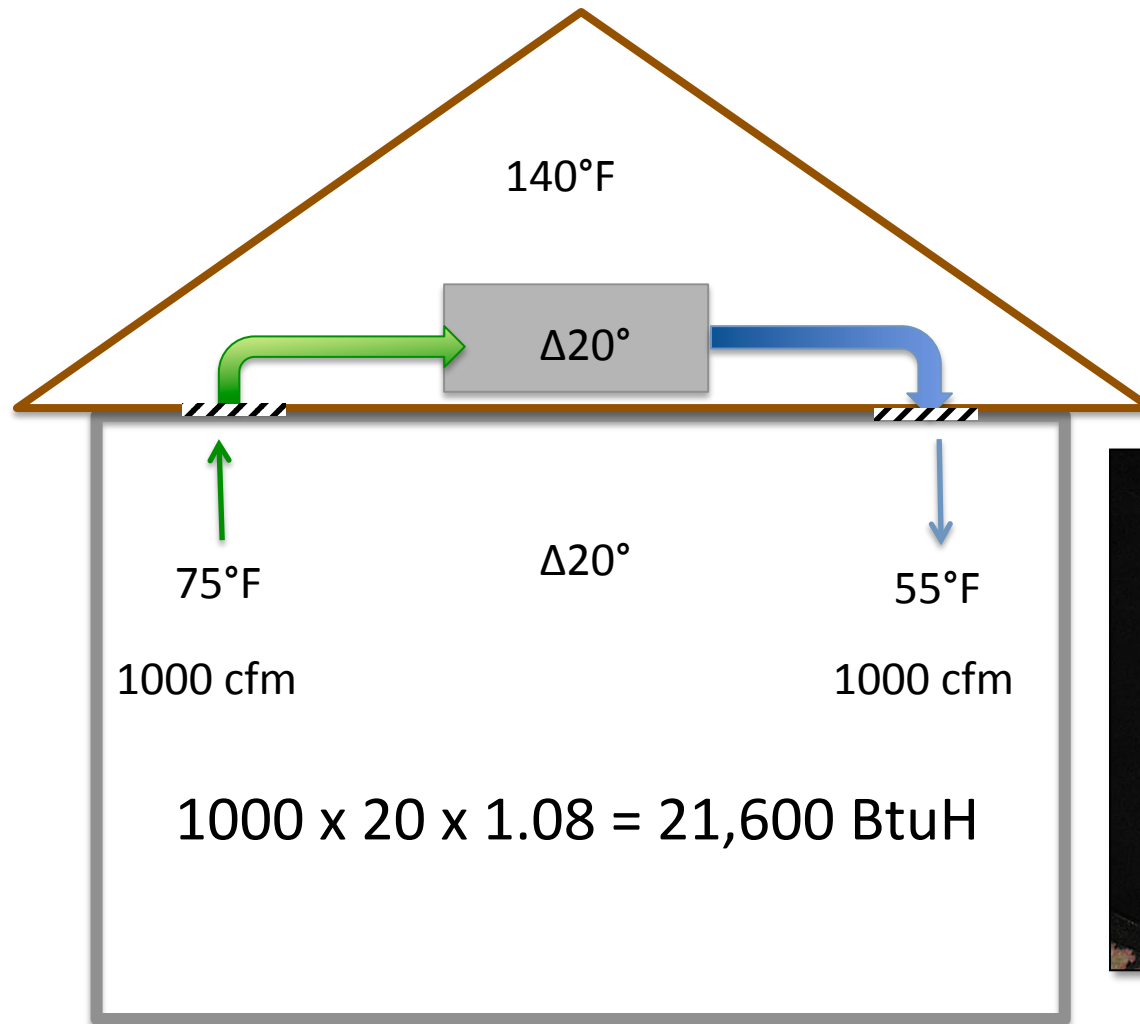
Positive pressure can push moisture into the wall system

A 15% Attic Return Leak

results in a

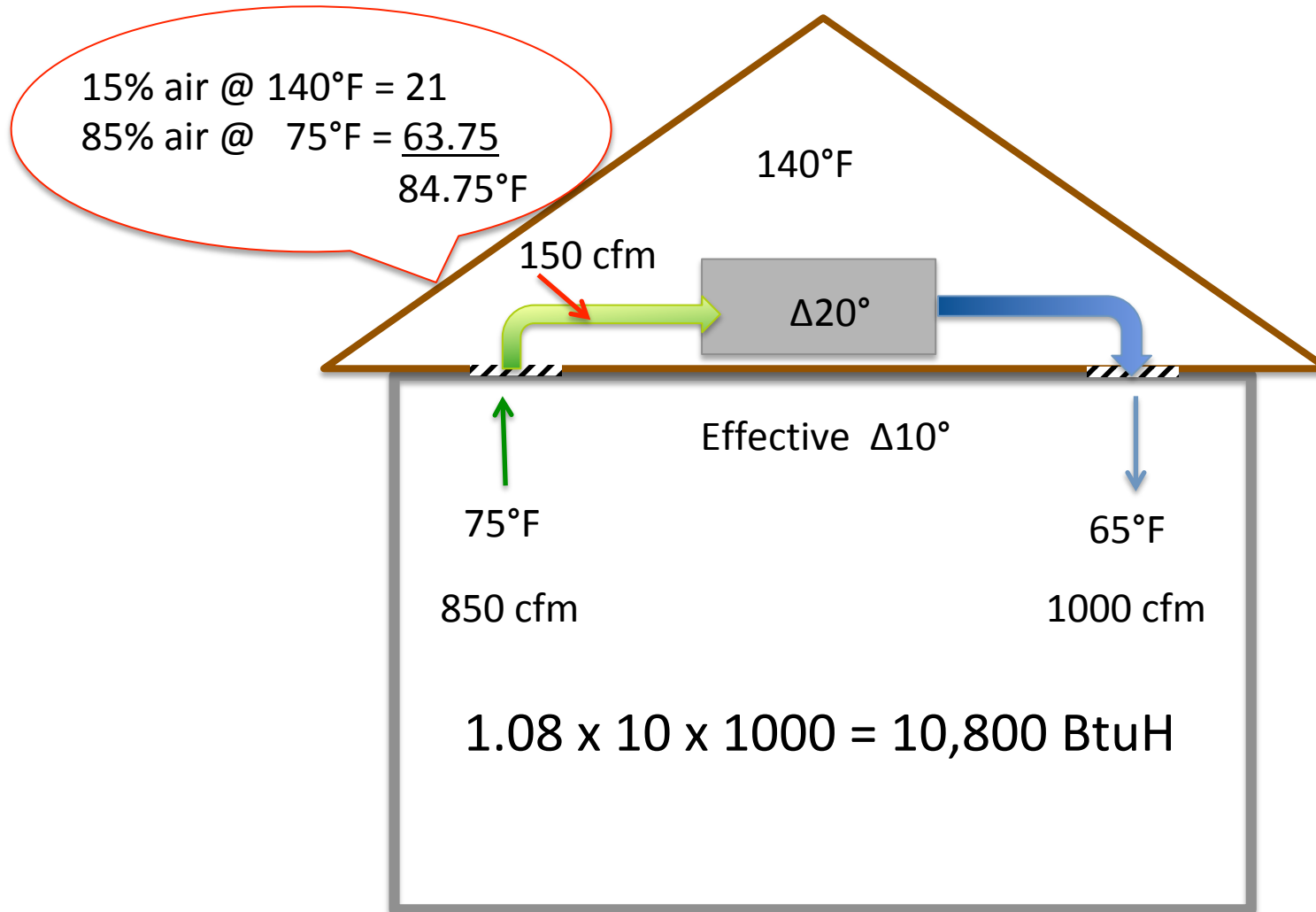
50% loss of system capacity

ZERO LEAKS, AIRTIGHT SYSTEM



Sensible Load Formula: $\text{BtuH} = \text{CFM} \times \Delta T \times 1.08$

15% Return Leak = ~50% Loss of Capacity



Sensible Load Formula: $\text{BtuH} = 1.08 \times \Delta T \times \text{CFM}$

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Purposes of Duct Testing



- ❑ Estimating HVAC capacity losses due to air leaks
- ❑ Diagnose leakage locations
- ❑ Measure the effectiveness of air sealing efforts
- ❑ Documenting and certifying leakage compliance for building code

Photo courtesy of Judy Rachel

Retrotec DucTester System



Duct Testing Equipment

A calibrated air flow measurement system designed to test and document the air tightness of forced air duct systems

Manometer

- A multi-functional differential pressure gauge
- Provides high resolution pressure measurements. These all have 2 independent measurement channels.
- One function accurately calculates air flow



Photo courtesy of Judy Rachel

DG-700



DM-2



DM32



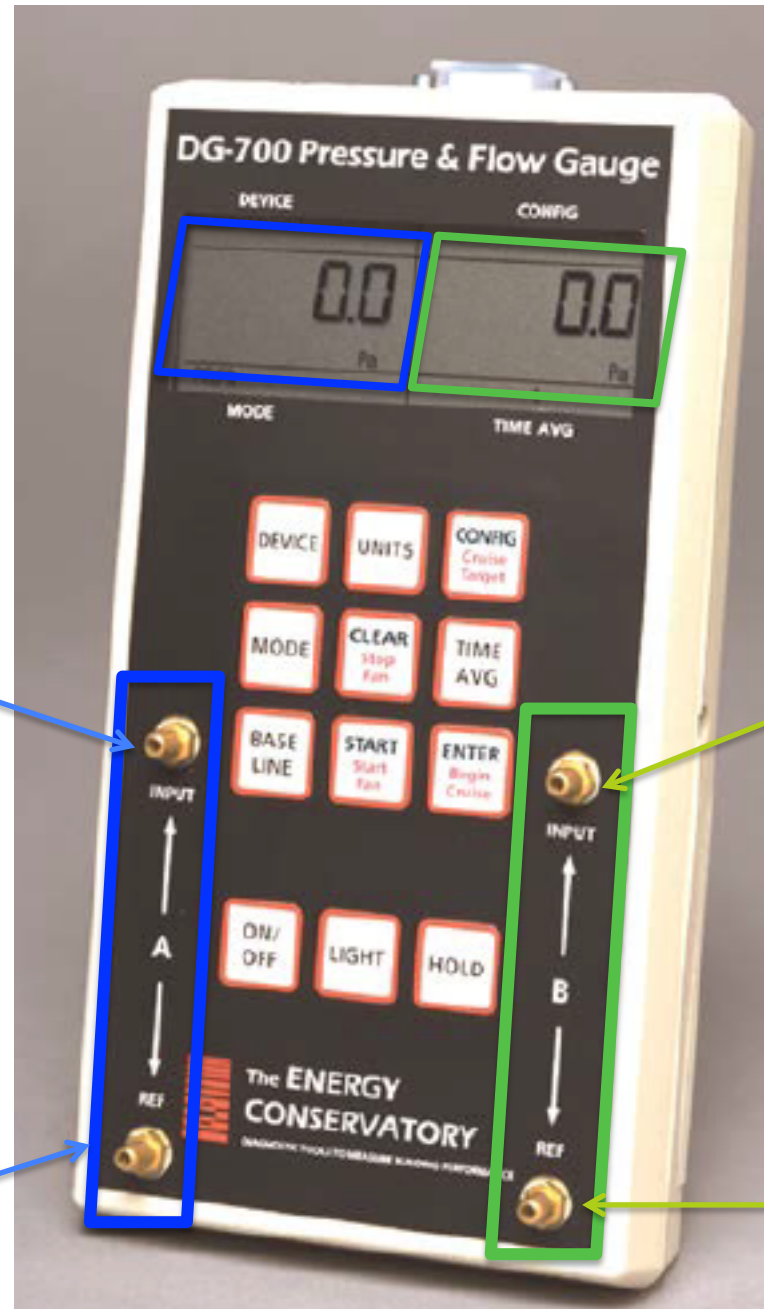
DG-1000

Channel A

Read-out is always pressure measurement

Channel A Input Tap

Channel A Reference Tap



Channel B

Read-out can be changed from pressure to Air Flow or Air Velocity

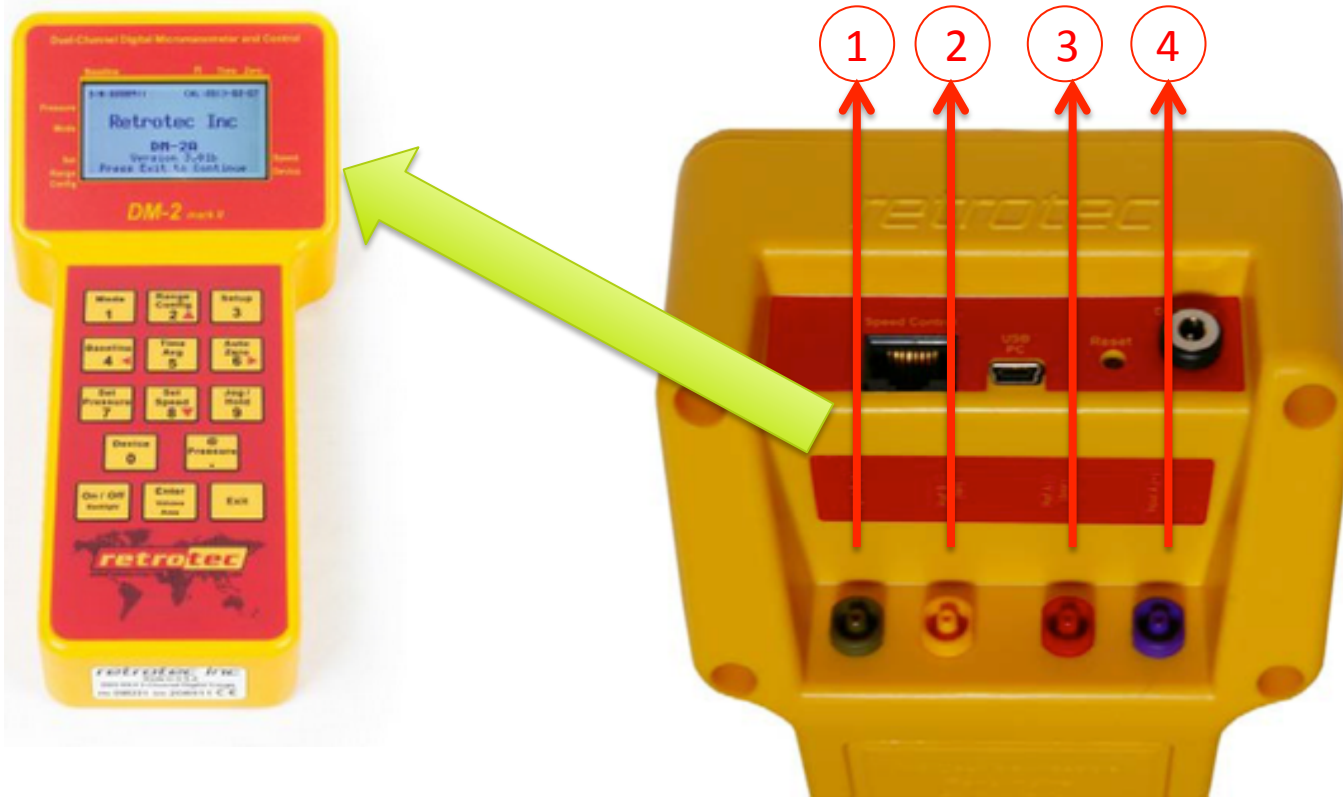
Channel B Input Tap

Channel B Reference Tap

Retrotec DM2

Gauge Ports

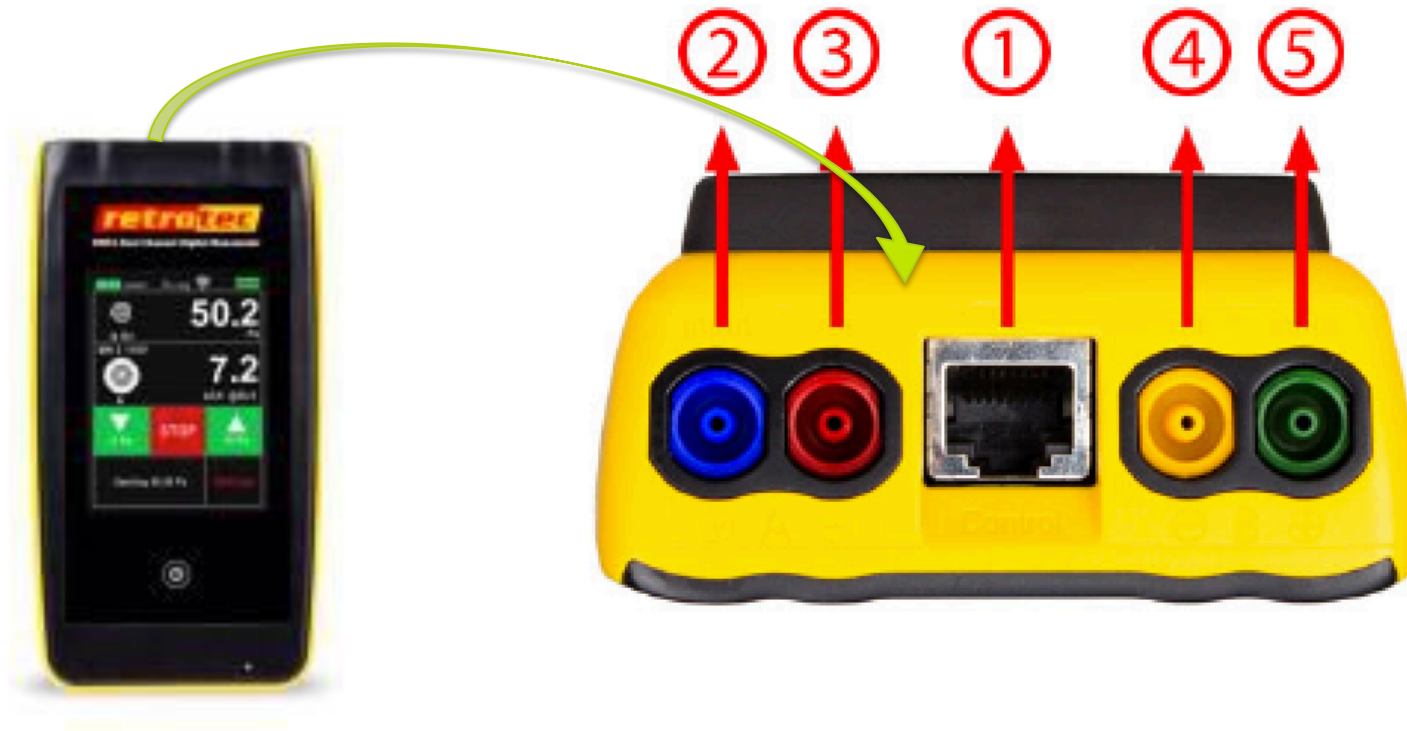
1	Channel B Input Tap
2	Channel B Reference Tap
3	Channel A Reference Tap
4	Channel A Input Tap



Retrotec DM32

Gauge Ports

1	Control cable port for fan speed
2	Channel B Input Tap
3	Channel B Reference Tap
4	Channel A Reference Tap
5	Channel A Input Tap



TEC DG-1000

Gauge Ports

Left to Right
Channel A Input
Channel A Reference Tap
Channel B Input Tap
Channel A Reference Tap



How Duct Leakage Testing Works

When there is:

1. A hole of a known size
2. A pressure difference across the hole
3. Air flow can be calculated

Duct airtightness is determined by measuring the leakage rate of the duct system when the duct system is subjected to a uniform test pressure.

The duct tester is connected to the return side of the ductwork.

The entire duct system is temporarily sealed off and pressurized or depressurized to 25 Pa.

The B side of the manometer converts the pressure reading to Air Flow

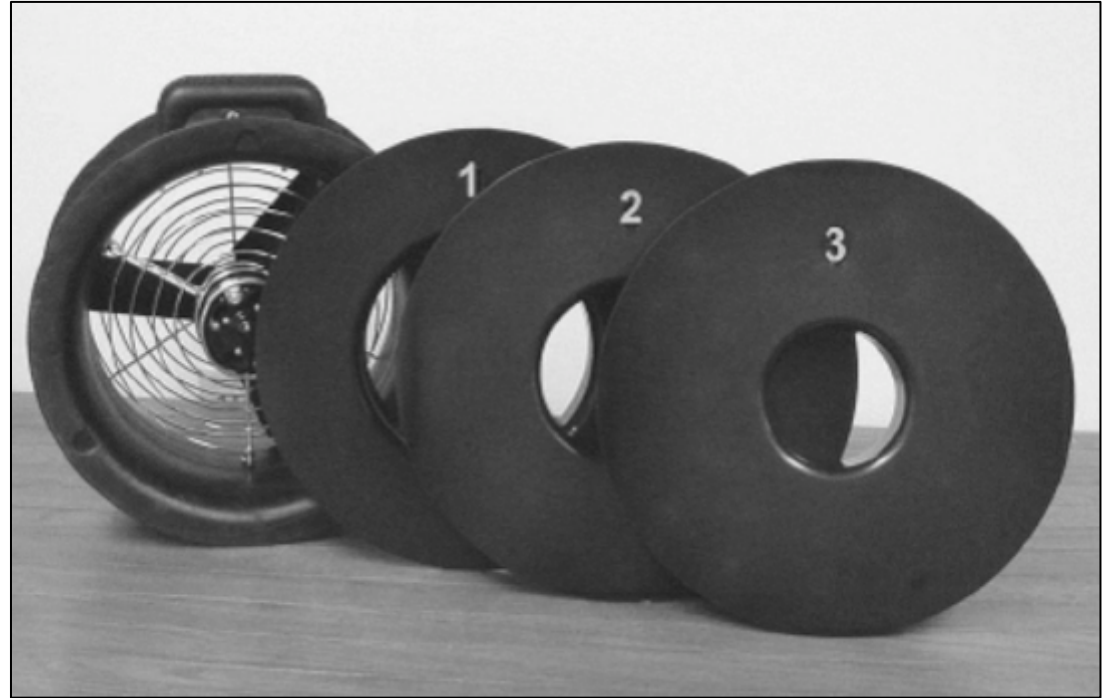
With the fan you create a 25 Pa pressure difference between the house/outside and the duct system



Hole of a known size

Holes of Known Size

TEC Rings



Flow Ring Configuration	Flow Range (CFM)
Open (no Flow Ring)*	1500 - 600
Ring 1	800 - 225
Ring 2	300 - 90
Ring 3	125 - 10
Ring 4	25 - 2.4

* The "Open" configuration can only be used when pressurizing the duct system

Holes of Known Size

Retrotec Range Plugs



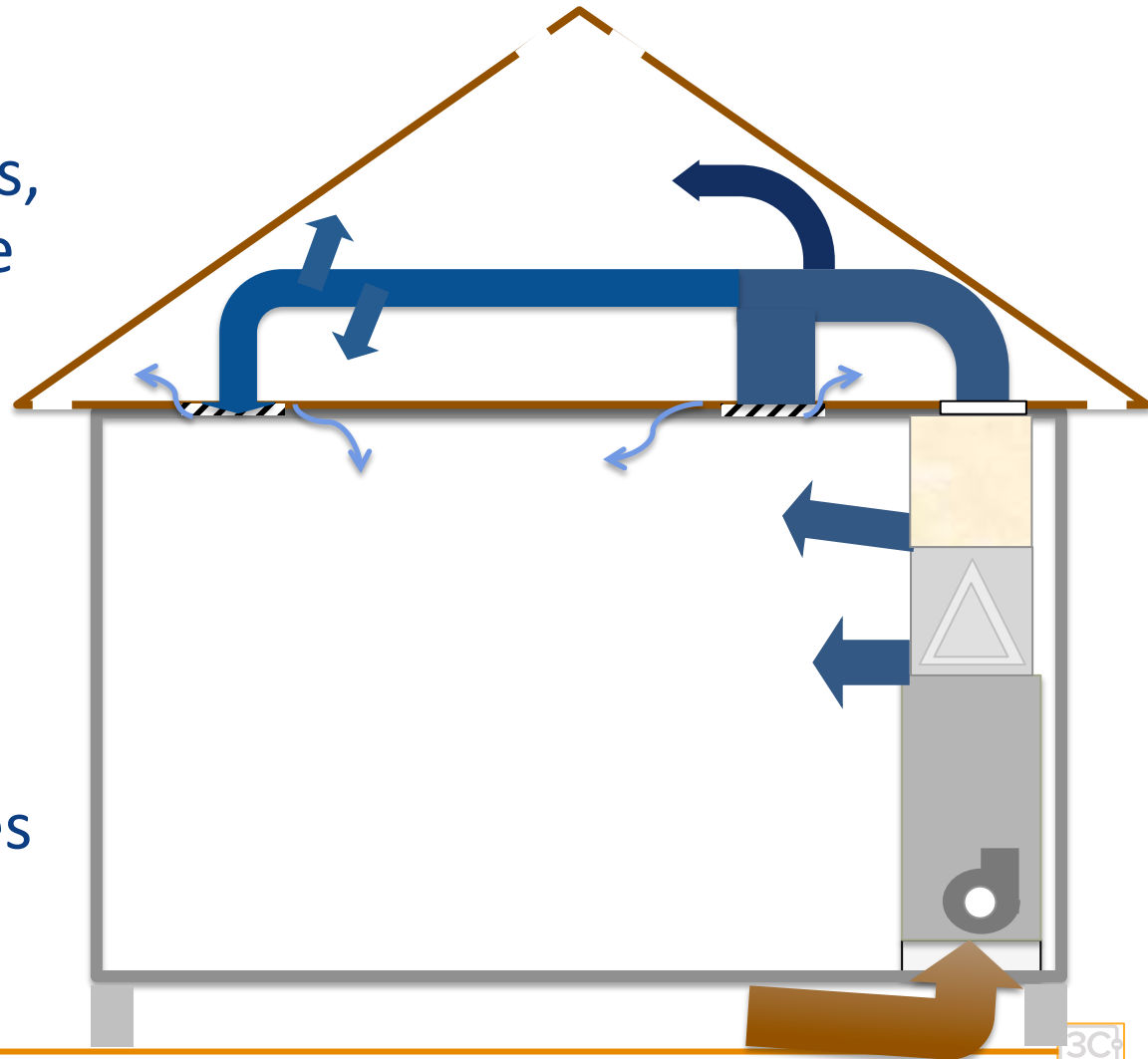
Retrotec DucTester fans can measure flows from 0.005 CFM to 800 CFM.
To find out specific Retrotec Range Plug flow capacities you must download (free) proprietary software from Retrotec website

25 Pascals Induced Pressure

- For residential systems, 25 Pascals (0.10 inches w.c.) is the most commonly used test pressure
- Research has shown that 25 Pa represents a typical operating pressure in many residential systems
- The calculated air flow at this test pressure differs from the leakage rate occurring in the duct system under actual operating conditions

Operating Condition Leakage

- Under actual operating conditions, pressures within the duct system vary considerably
- Highest pressures occur near the air handler
- Lowest pressures occur near the grilles



Two Main Duct Leakage Tests

Total Duct Leakage

- Measures the total amount of air leakage from a duct system
 - Air leaks to both conditioned and unconditioned spaces

Duct Leakage to the Outside

- Measures only the air leakage to “outside”, the unconditioned spaces
 - Neutralizes the duct leakage to the conditioned spaces by pressurizing or depressurizing the house to the same pressure as the ducts are being pressurized or depressurized to

Duct Testing & Beyond

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House Set-up

Adjust all mechanical equipment (including the air handler fan) so that they do not turn on during the test.



Thermostat



Water Heater



Bathroom/
Laundry fans



Kitchen exhaust



Attic exhaust fan



Clothes dryer

Set-up Continued



Remove all filters from the duct system



Temporarily seal off all supply and return grilles (except the return being used to connect the test equipment to the duct system)



Temporarily seal off all ventilation air inlets which are directly connected to the duct system

Improper Sealing



Photo courtesy of Retrotec

Boots are often not sealed to the interior finish.

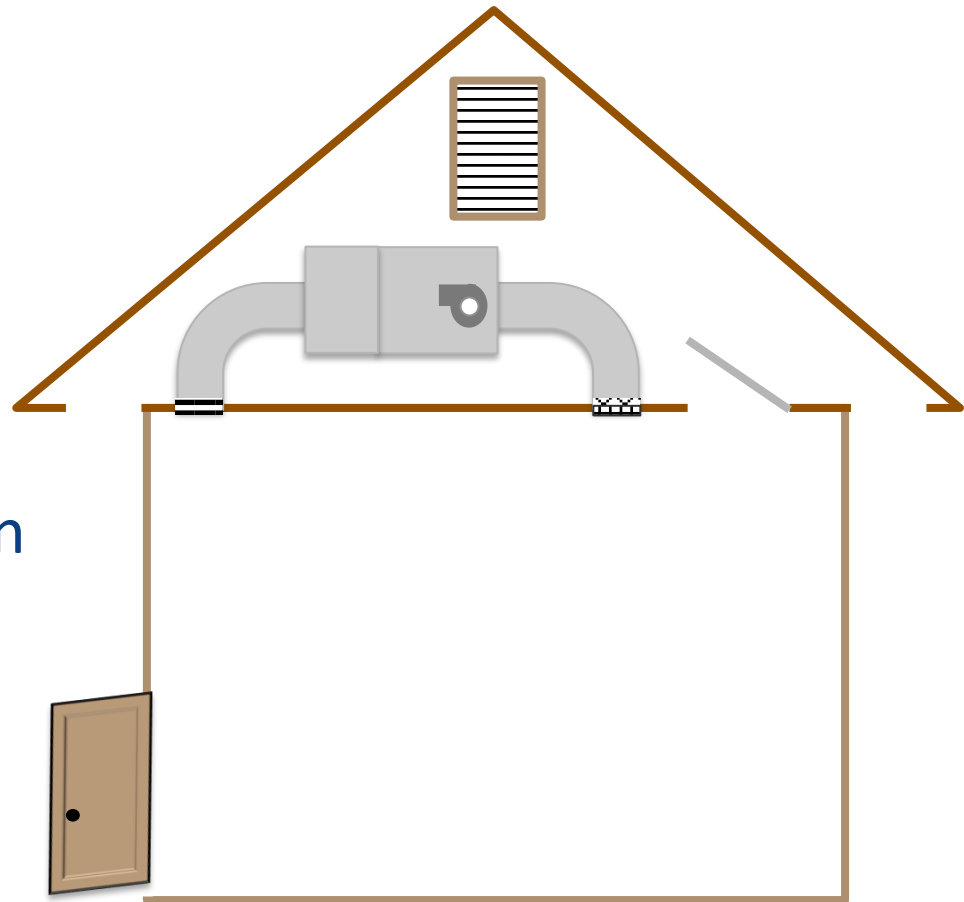
How well you seal off the registers will have a large impact on the accuracy and repeatability of the test results



Photo courtesy of Judy Rachel

House Set-up

- Open a door or window between the house and outside.
- If **ducts** run through unconditioned spaces open vents, access panels, or doors between those spaces and the outside to eliminate pressure changes during the test procedure.



House Set-up

- If the duct test fan will be installed in an **unconditioned space** (e.g. connected to an air handler located in a garage or crawlspace) open vents, access panels, or doors between those spaces and the outside.
- Run a hose from the A side reference tap into the house to measure duct pressure with reference to the house.
- *Pressure changes during the test in spaces containing ductwork or the test equipment fan can bias the test results.*



Photo courtesy of Energy Conservatory

Equipment Set-up

- Install at large central return
- Always position fan to minimize bends in the flex duct



Photo courtesy of Energy Conservatory

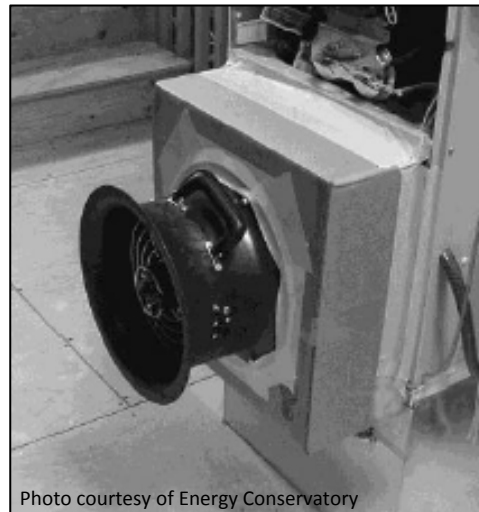
Fan can be installed directly to return grille



Photo courtesy of Judy Rachel

Equipment Set-up

- Installation at air handler fan cabinet – blower compartment access panel
- If air flow is obstructed by any components build out with small cardboard box for attachment
- Duct testing equipment can be attached with or without the use of the flexible extension duct



Equipment Set-up

- Install a ring based on your best guess of how leaky the system is
 - It is easy to change the ring if your best guess was not the best choice
- Rings are always installed on the inlet side of the fan



Photo courtesy of Retrotec

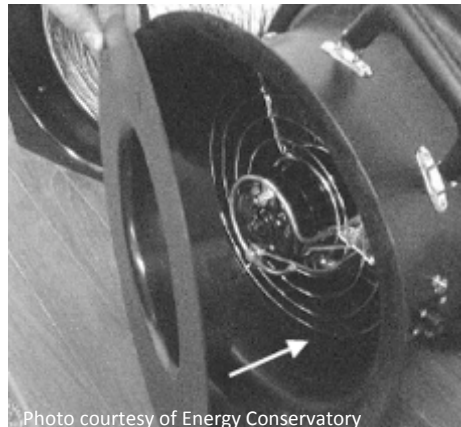
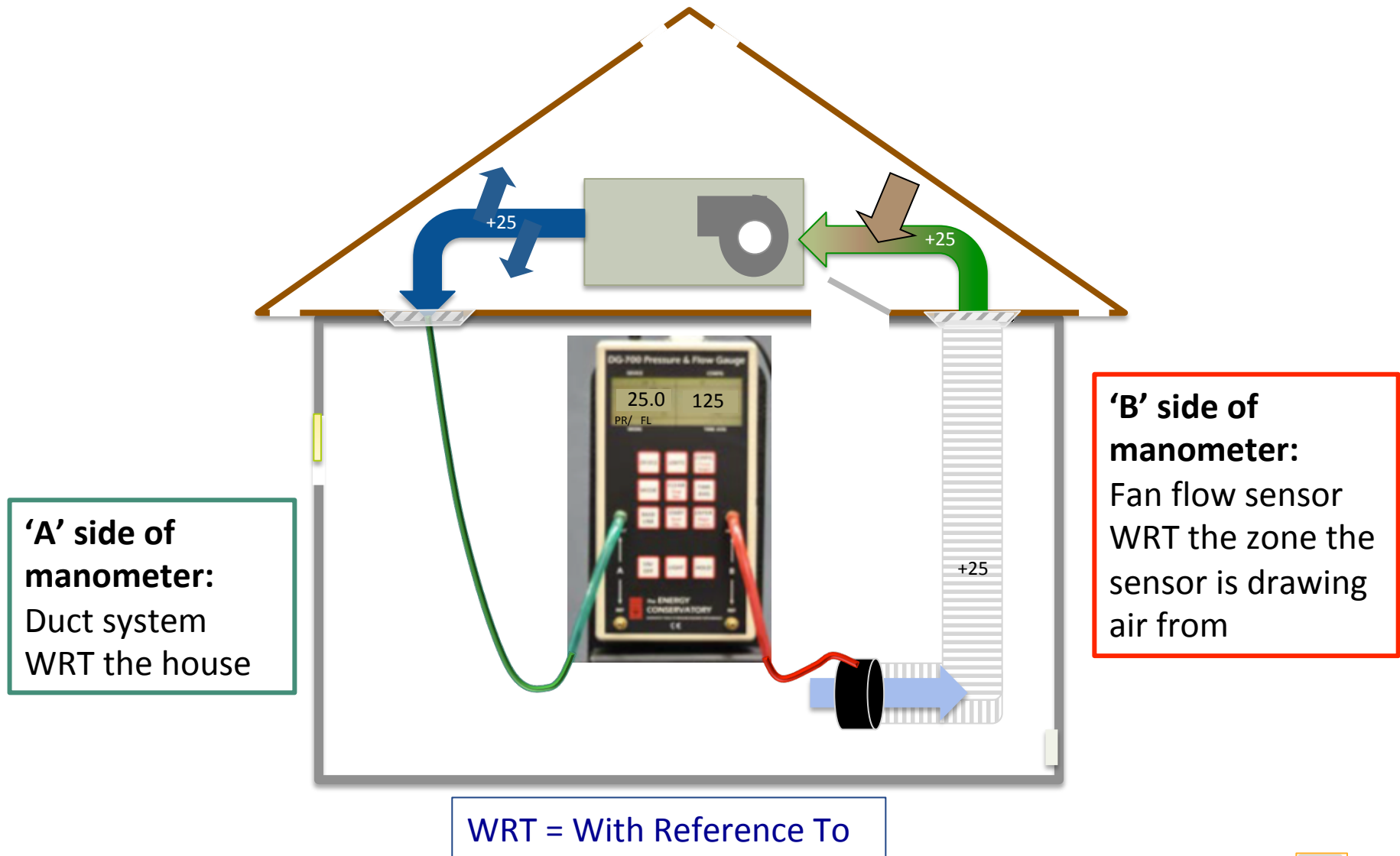


Photo courtesy of Energy Conservatory

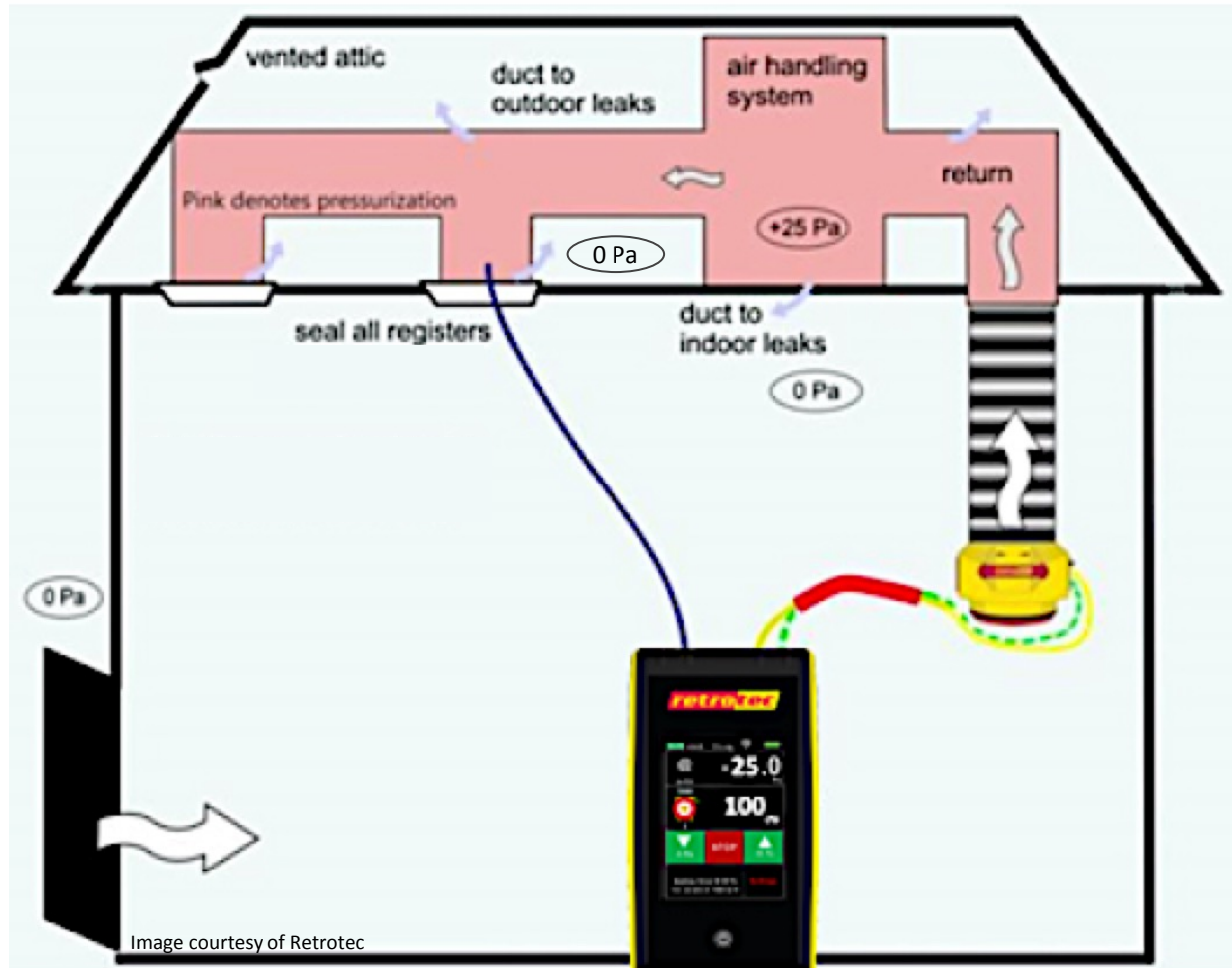


Photo courtesy of Energy Conservatory

TEC - Total Duct Leakage



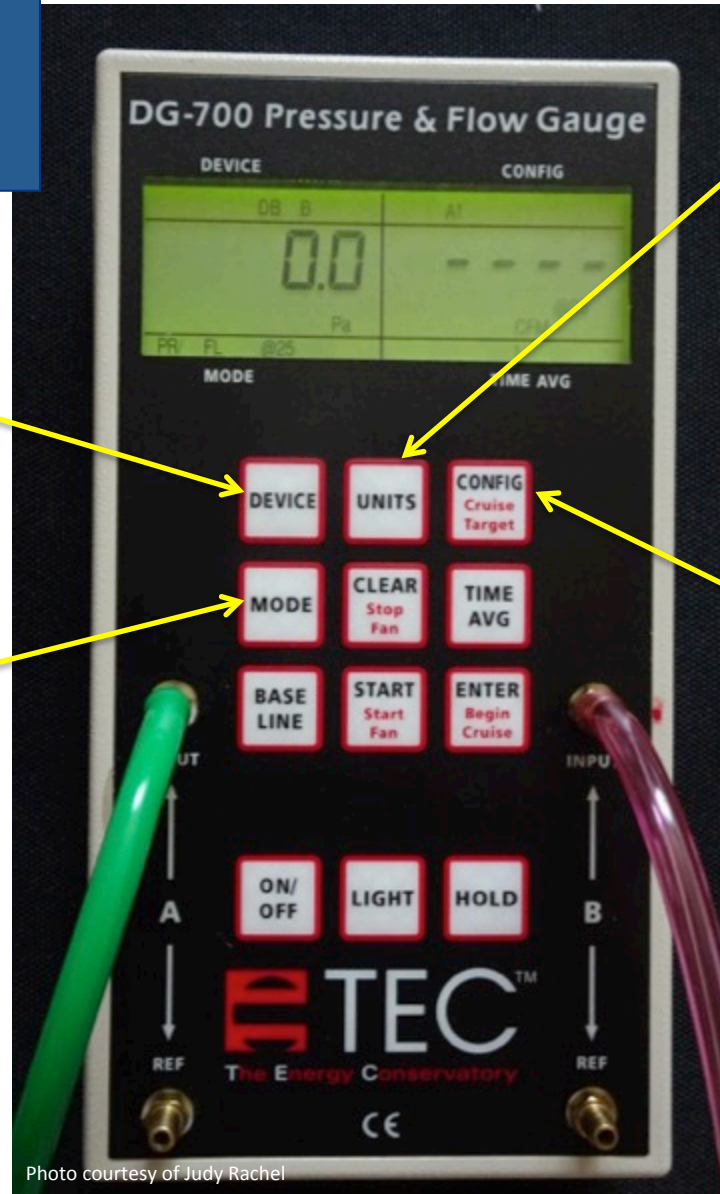
Retrotec – Total Duct Leakage



Program Manometer

Step 2: Choose the correct DEVICE

Step 1: Set MODE
Can use either -
PR/ FL or PR/ FL @ 25



Depending upon manometer UNITS often defaults to CFM

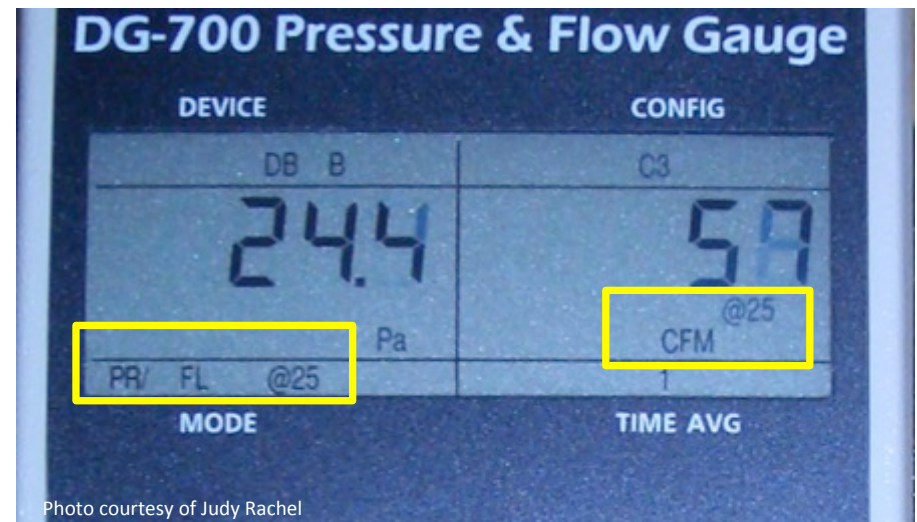
Step 3: CONFIGURE
Tell the manometer what ring you are putting on the fan. If you need to physically change the ring at the fan remember to change the ring choice in the manometer.

Photo courtesy of Judy Rachel



PR/ FL @25 Mode

- Gauge displays CFM@25 on Channel B. (Can't Reach Pressure Factor is built-in to the flow reading)
- Saves time - no need to adjust test pressure to exactly 25 Pa - just get close (20 – 30 Pa).
- In very leaky duct systems, PR/ FL @ 25 displays a leakage estimate if duct pressure is at least 5 Pa.



At 24 Pa the CRP factor is 1.02
If the manometer were in PR / FL the B side would be displaying 56 CFM.

With the manometer set to PR/ FL @25 the manometer is multiplying 56 CFM by the CRP factor of 1.02 and displaying 57 as the result at 25 Pa

Adjust for Base Pressure

To Baseline or Not To Baseline?

- With the fan sealed off notice if there appears to be a base pressure greater than 1 Pa
- Run Baseline function if pressure in duct system is 1 Pa or greater

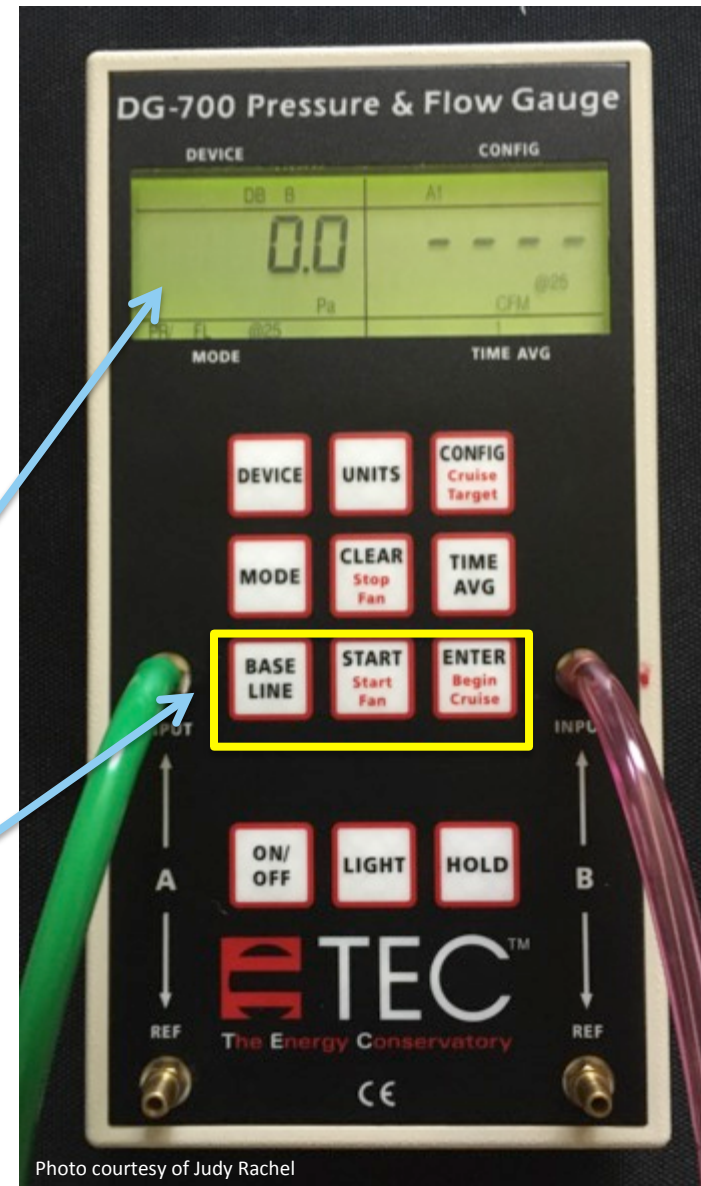


Photo courtesy of Judy Rachel

Fan Speed Controller

Receptacle & pressure tap on fan

Connect tube from
Channel B Input tap
to fan tap

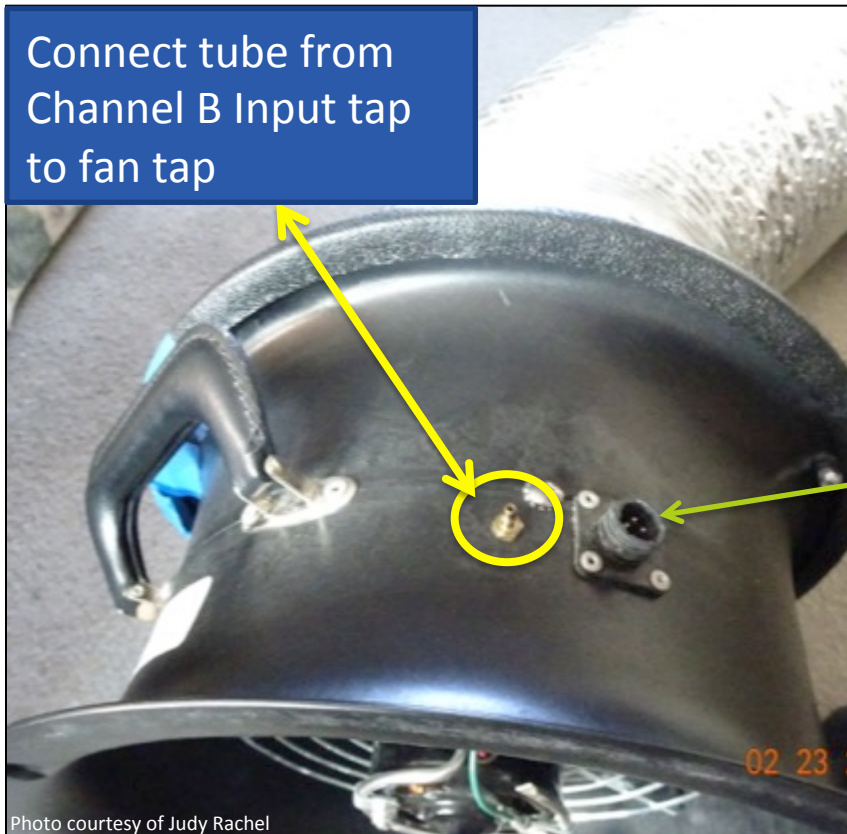


Photo courtesy of Judy Rachel

Fan speed controller & manometer mounting board



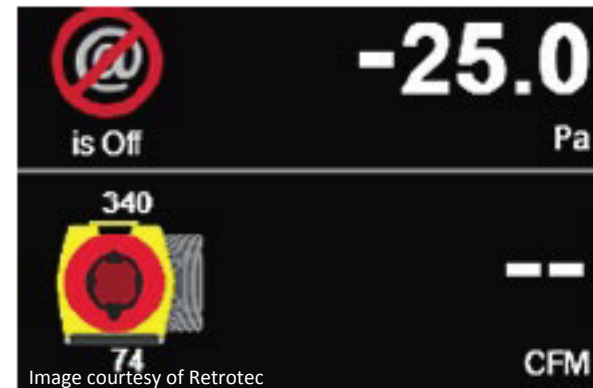
Photo courtesy of Judy Rachel

Total Duct Leakage Test Procedure

- Once house and equipment are set up decide whether or not to adjust for any base pressure difference
- Turn on the test fan, bring duct system to 25 Pa (+/- 5 Pa if using the @ 25 mode)
 - Decide if you have the correct ring installed
- Note the air flow displayed on the B side of the manometer
- Check the tape job to ensure all grilles are sealed tight
 - Fix any that are not sealed well
- Record the air flow displayed on the B side of the manometer

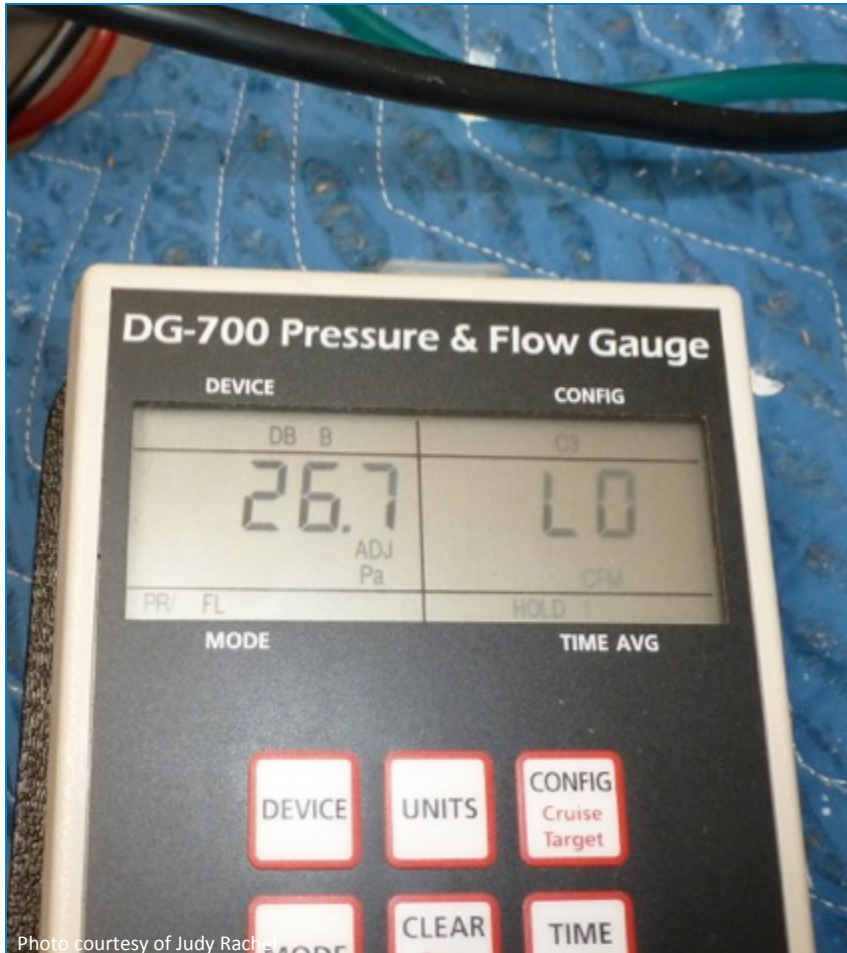
“----” Displayed on Channel B

- **Retrotec** – Install a flow ring or change to a smaller flow ring.
- **TEC** – when continuously displayed the pressure on Channel A is below 5 Pascals. Install a larger Flow Ring or remove the Flow Rings to generate more fan flow.



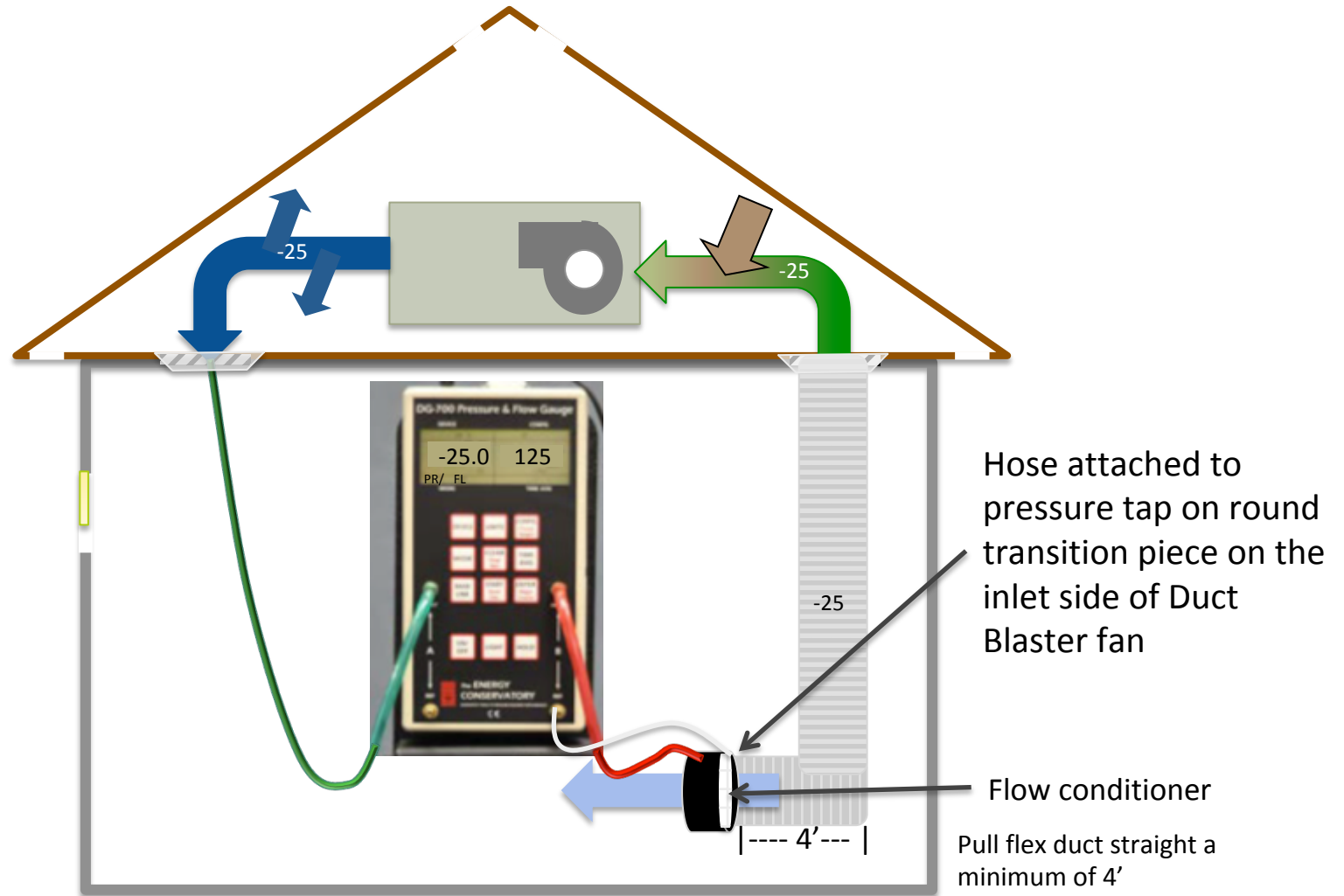
Change the configuration setting on the manometer to match the new ring size.

“LO” Displayed on Channel B



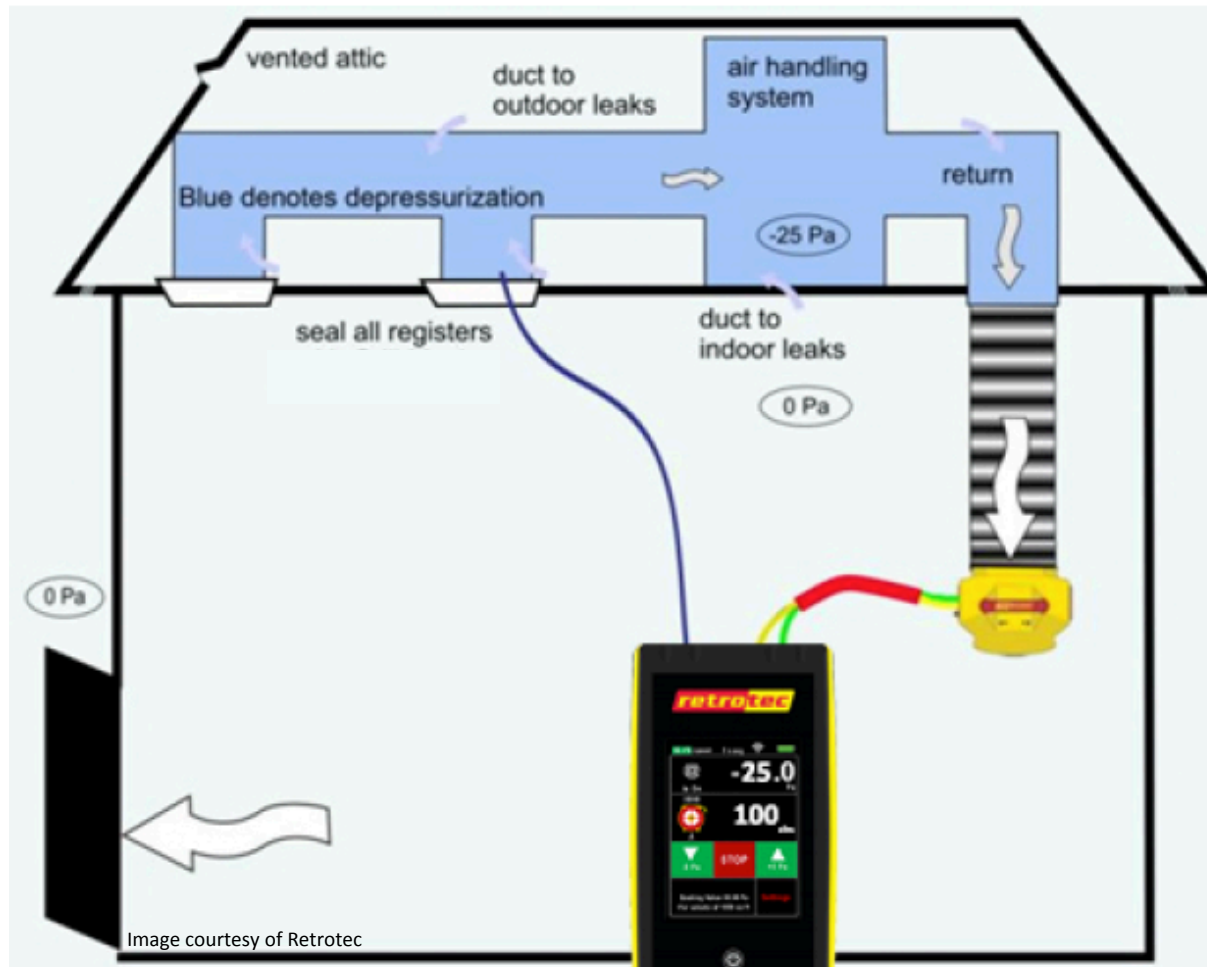
- When “LO” is displayed either continuously or fluctuating with a flow reading the pressure signal from the test device is too low to provide a reliable air flow reading
- If possible install a flow ring or a smaller flow ring
- **Change the configuration setting on the manometer**

Pressurize or Depressurize?



Both pressurization and depressurization tests typically provide similar test results. Use of one procedure over the other is primarily a matter of personal choice.

Retrotec – Total Duct Leakage Depressurization Set-up



Depressurization

Retrotec fan models with a green tube are set up with 2 tubes connected to the fan and manometer. With these duct testers after putting a ring on the fan inlet side attach the flex duct over the fan inlet.



Photo courtesy of Retrotec

TEC duct testers need a flow conditioner installed when depressurizing a duct system. An additional tube needs to be connected between the fan and the manometer as well. The flex duct is installed to the fan inlet.



Photo courtesy of Energy Conservatory

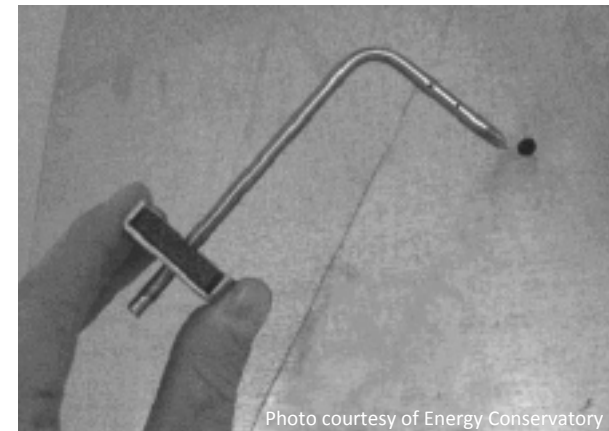
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Location to Measure Duct System Pressure

- Supply closest to air handler
 - Use of a static pressure probe is unnecessary
- Supply Plenum
 - Use a static pressure probe
- Main supply trunk
 - Use a static pressure probe

★ In zoned systems all dampers must be open, or will need to test each zone separately. ★



Point probe into air stream

Where to Install the Equipment

- In single, double or triple returned systems, the largest and closest return to the air handler is a good choice
- In multi-return systems (a return in every room), installing the duct testing equipment at the air handler cabinet is the best choice
- Install in middle of the grille



Airflow Restrictions

- Airflow restrictions cause back pressure against the fan reducing maximum operating capacity of the fan
 - Large back pressures degrade the fan calibration
- TEC is calibrated to 100 Pa of back pressure
 - Maximum airflow against 50 Pa of back pressure decreases the fan's ability to move air from 1500 cfm to 1350 cfm without the flex duct and down from 1250 cfm to 1000 cfm with the flex duct
- Retrotec provides no information on back pressure calibration limitations

Airflow Restrictions



Measure for
back pressure



How to Install

When attaching the square to round transition piece to cardboard, cut a square hole in the cardboard approximately one inch smaller than the outer flange of the transition piece



Photo courtesy of Energy Conservatory

Greatest Flow Measurement Accuracy

- Install the flow ring with the smallest opening area, while still providing the necessary fan flow to pressurize the duct system to the test pressure.
- Stand at least 12 inches from the side of the fan inlet. Standing directly in front of the fan may affect the flow readings and result in erroneous measurement

Do Not Perform Duct Test

- If the duct system is wrapped in a material containing asbestos or suspected to contain asbestos



Do Not Perform Duct Test

No return duct



Return is pulling air directly from the crawlspace underneath the house



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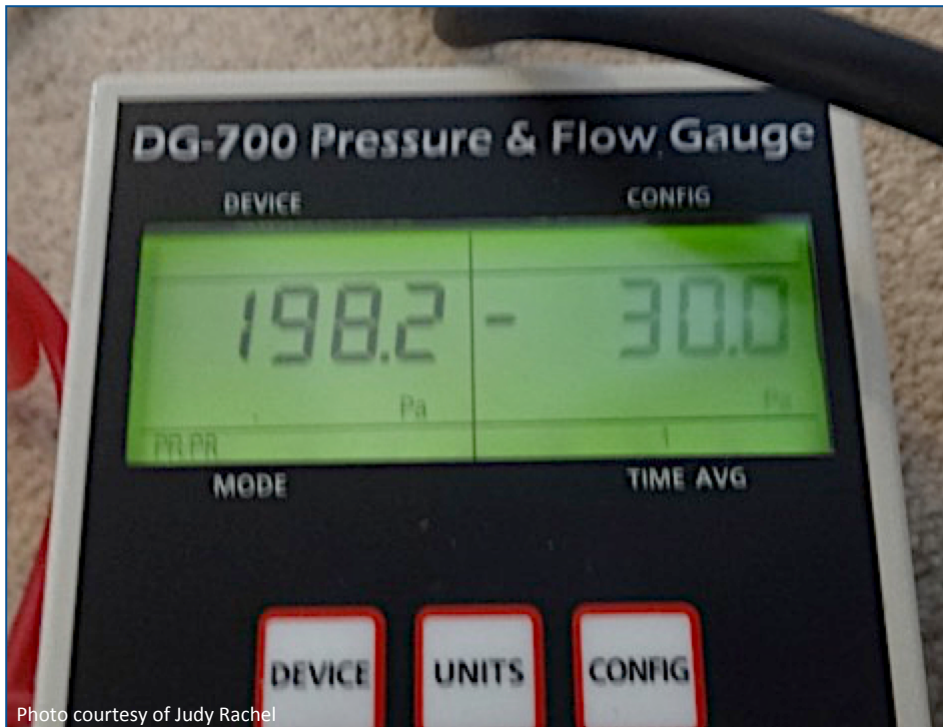


Photo courtesy of Judy Rachel

Half Nelson

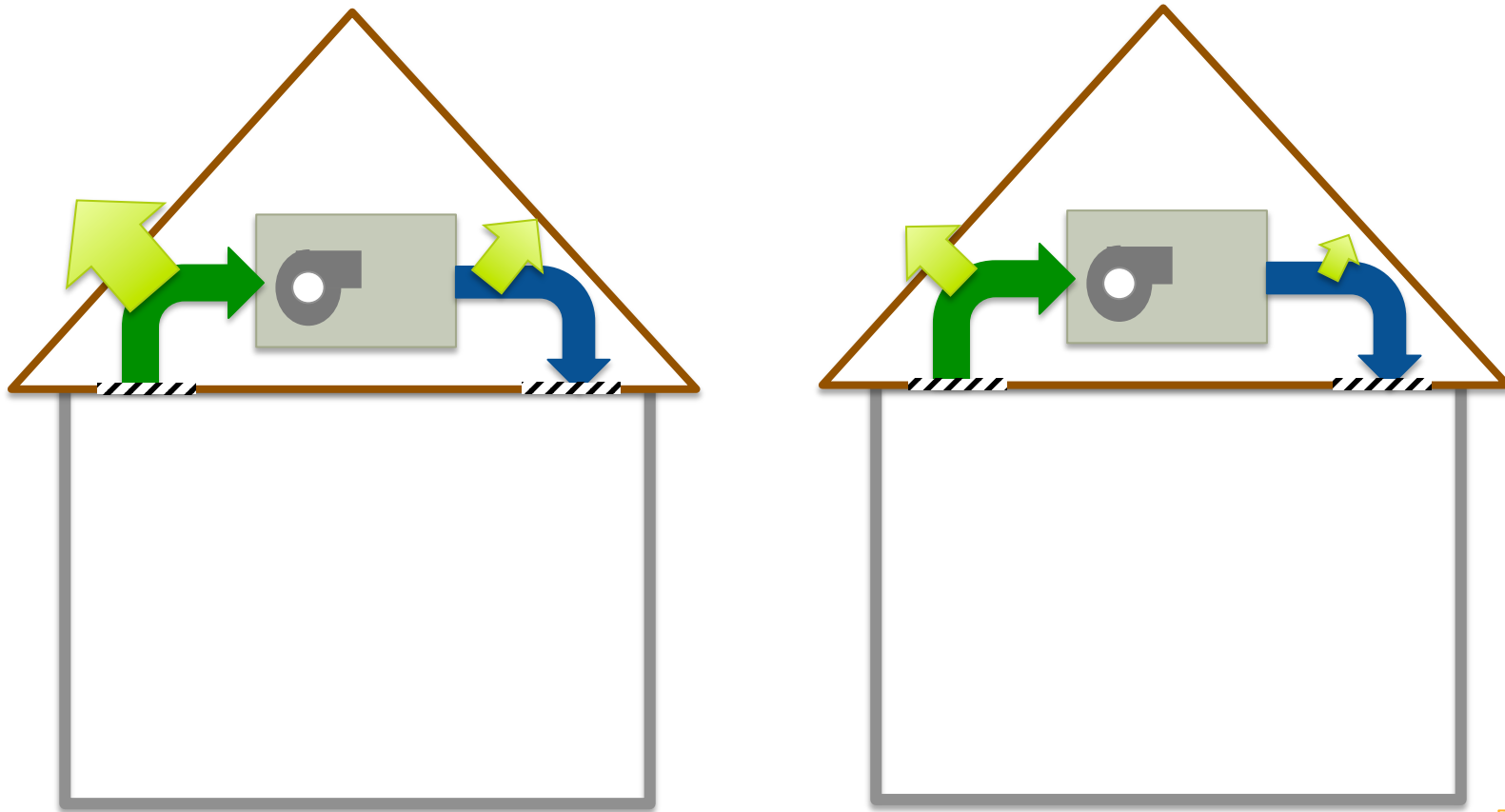
Dominant Duct Leakage

The Half Nelson is a fast method which estimates the **ratio** between the total supply leakage area and the total return leakage area.

Supply and return leaks have different impacts on energy use.

Ratio Relationship

The relative size of the holes is the same in these two pictures. The supply side duct leakage in these pictures is $\frac{1}{2}$ that of the return side duct leakage. A ratio does not tell us the actual size of the holes only their relationship to each other.



Half Nelson

Perform after duct leakage test with all registers/ grilles still sealed and duct tester still set-up:

- Set manometer to **PR\PR**
- Close off the duct tester fan opening
- Turn on the thermostat – use fan only
- Reading will quickly display on manometer – push Hold button
- Quickly remove tape or nylon fan cap
- Quickly turn thermostat to off

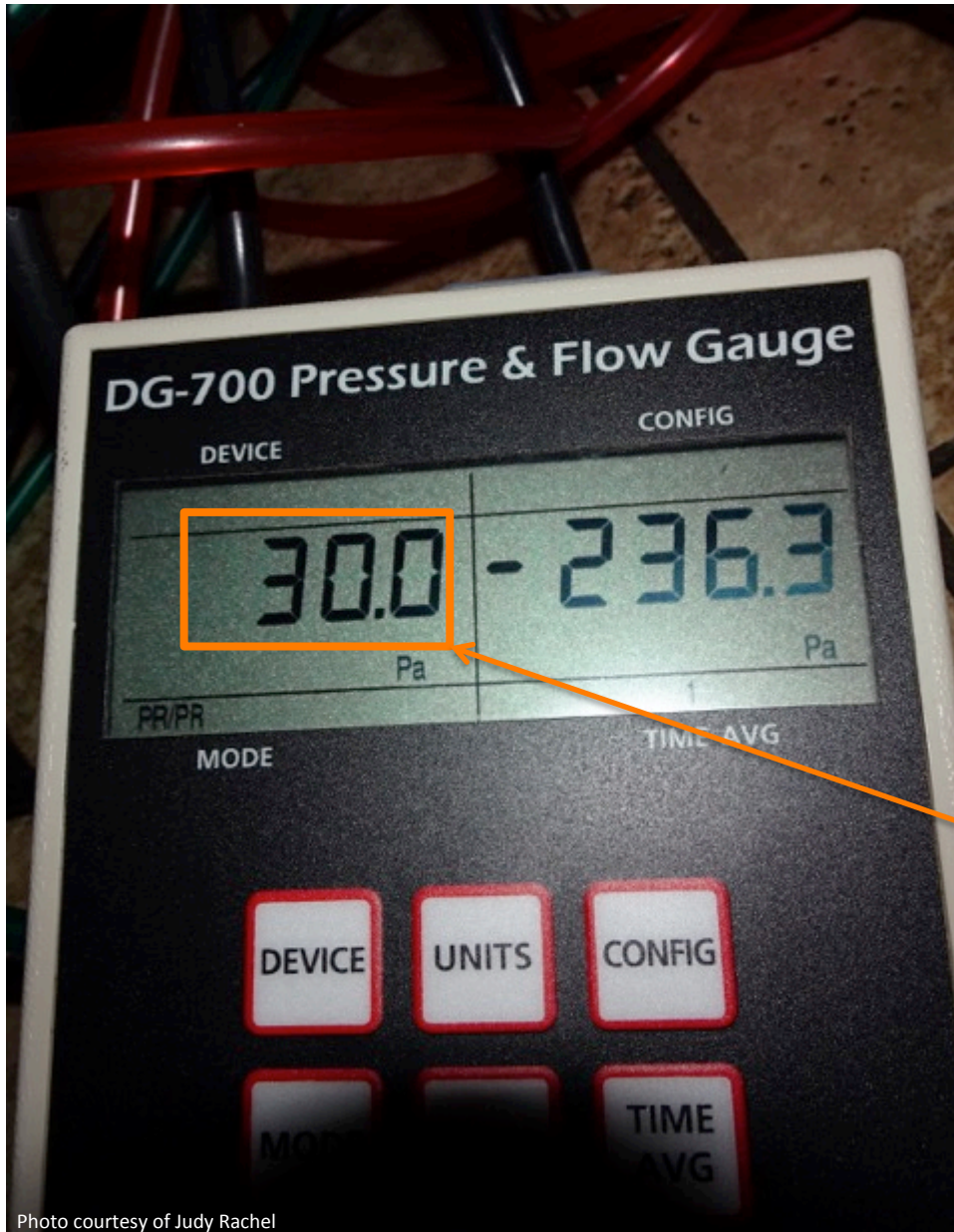


Photo courtesy of Judy Rachel

Interpreting Half Nelson results

The side with the lower pressure reading is the leakier side.

The B channel is the return side and will always be a negative number.

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Duct Leakage To The Outside



House & Equipment Set-up

Close door or window that was opened for total duct leakage test

Close any access to unconditioned spaces

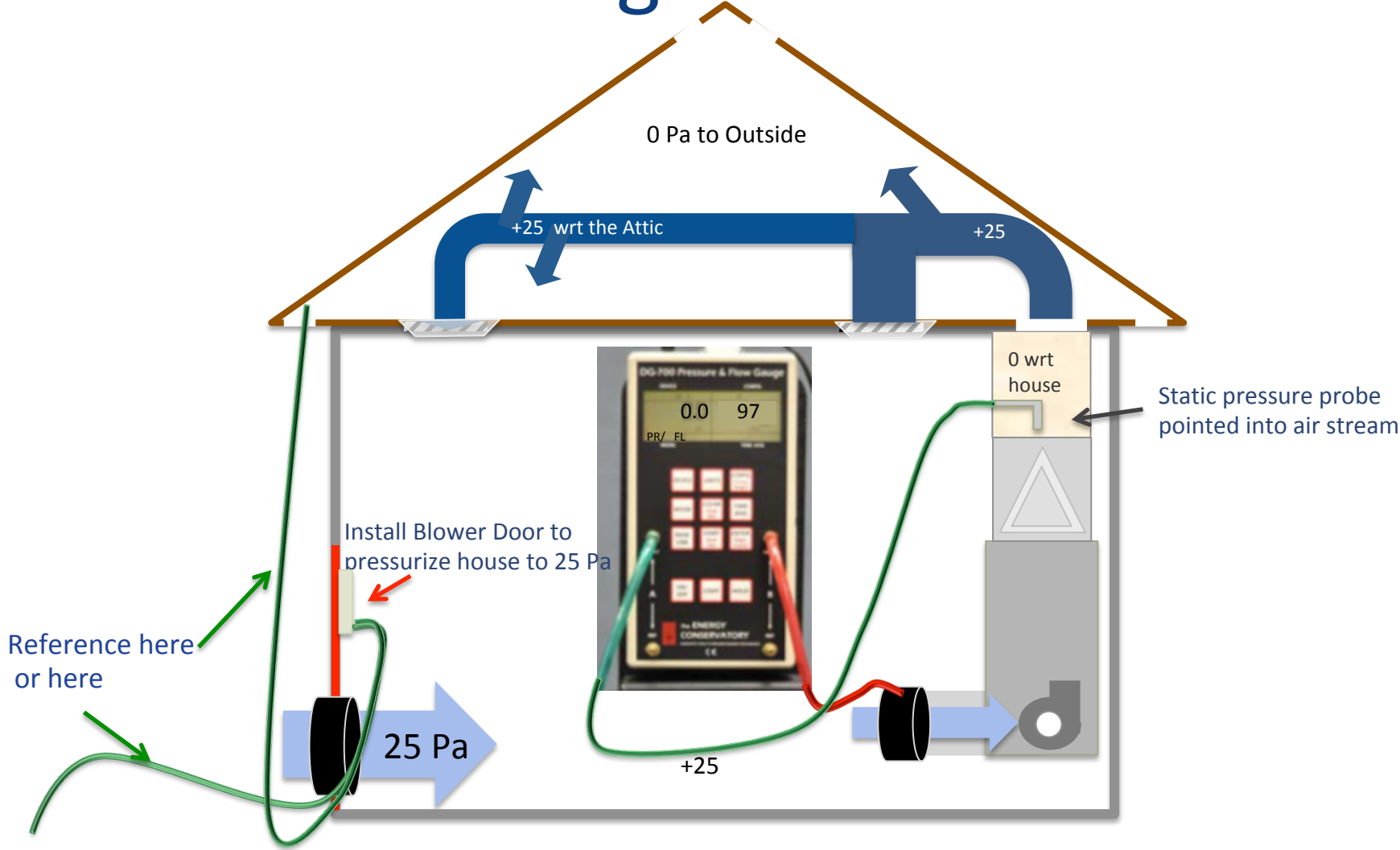
Set-up a blower door, will pressurize or depressurize house to 25 Pa

Duct test manometer needs to be set to PR / FL

DLTO Test Procedure

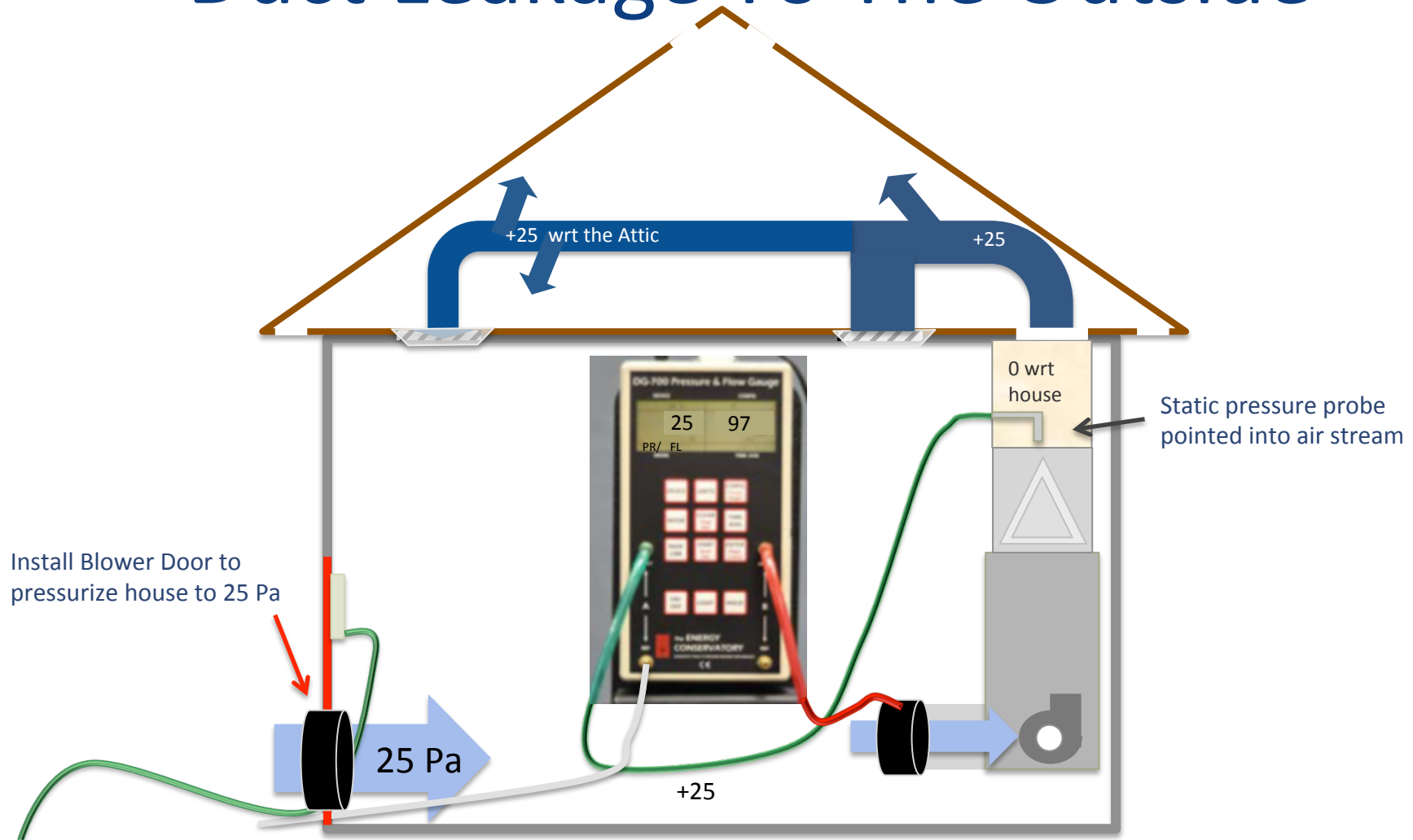
- Begin with duct test equipment off
- Bring house pressure to 25 Pa with the blower door
- (De)Pressurize the duct system to a neutral pressure with house
 - If Channel A reference tap is open to house bring duct pressure to '0' (zero)
 - If Channel A is referencing the outside bring duct pressure to 25 Pa
- Confirm house pressure is 25 Pa, adjust if not
- Confirm duct pressure is 0 Pa (or 25 Pa) adjust if not
 - Will have to adjust both a couple of times
- Once pressures are stable record B Channel flow on duct testing equipment

Duct Leakage To The Outside



The amount of duct leakage to the unconditioned side of the thermal/pressure boundary, i.e. outside

Duct Leakage To The Outside



The amount of duct leakage to the unconditioned side of the thermal/pressure boundary, i.e. outside



Photo courtesy of Judy Rachel

Duct Leakage to the Inside

- ★ A cause of comfort issues
- ★ Can be a source of filter bypass
- ★ Can contribute to increased soil gas entry
- ★ Can cause CAZ depressurization
- ★ Is not a large energy penalty

Duct leakage to the inside can be just as important as leakage to the outside

Total Leakage vs. Leakage to the Outside

Total Duct Leakage

- Only need duct testing equipment
- Shorter set-up time
- Can perform at rough-in
- Test is quick once set-up is done
- Measures all leaks in the entire system

Duct Leakage to the Outside

- Need blower door and duct testing equipment
- Longer set-up time
- Must wait until building enclosure is finished
- Test takes longer to perform
- Misses leaks to the inside

Comparing DLTO to TDL

Duct Leakage to the Outside

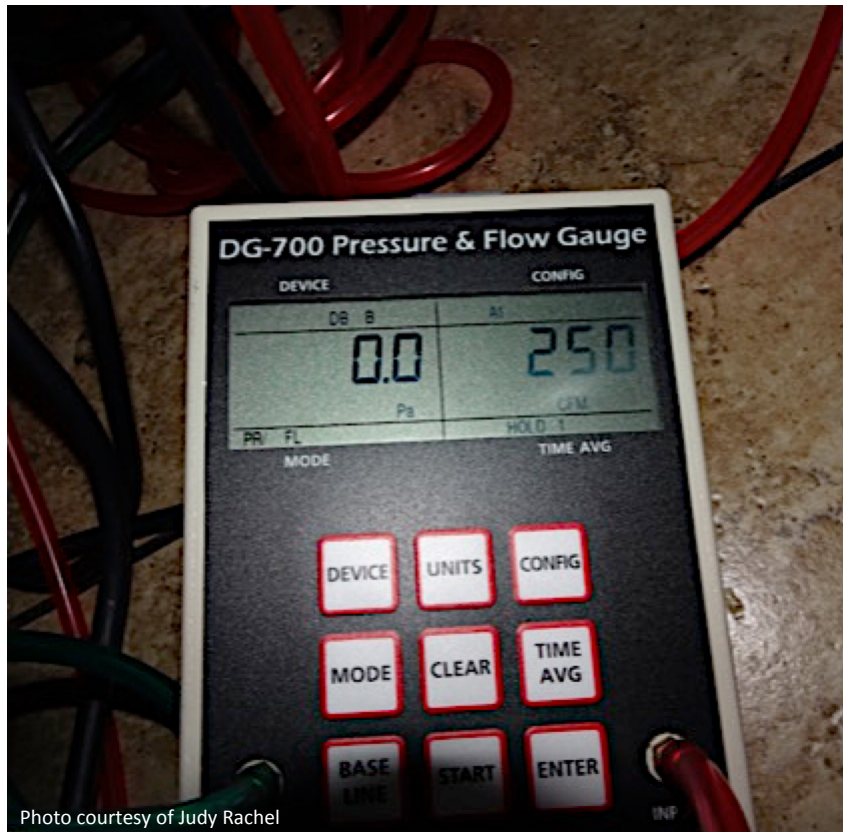


Photo courtesy of Judy Rachel

Total Duct Leakage

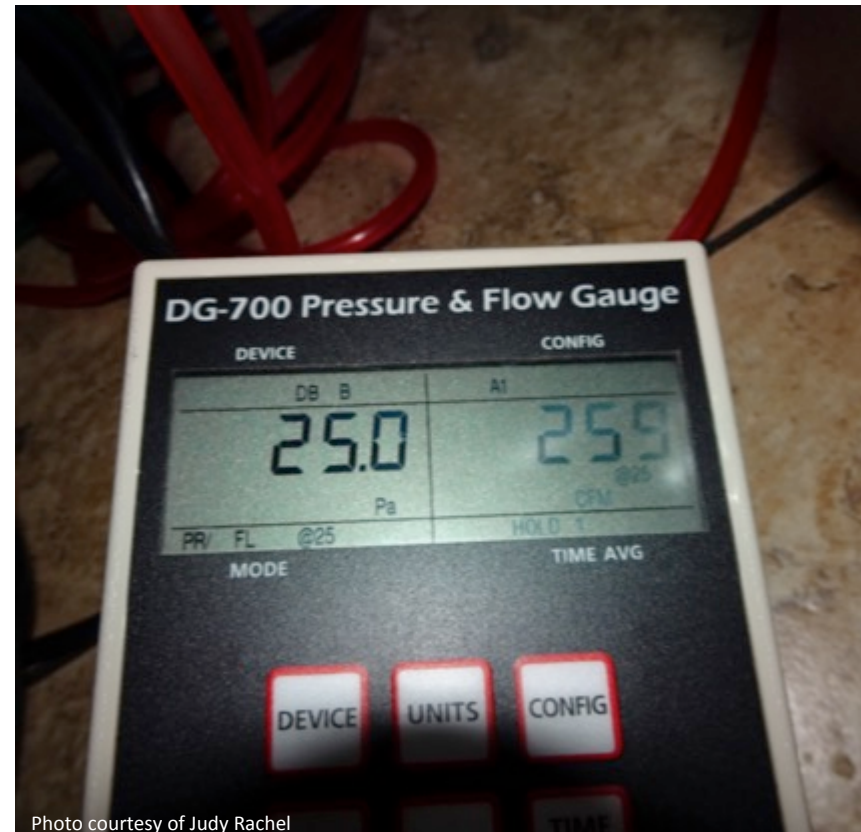


Photo courtesy of Judy Rachel

Duct Testing & Beyond

- ✓ Role of the duct system
- ✓ Significance of duct leakage
- ✓ The principles of duct testing
- ✓ Total duct leakage test
- ✓ Duct testing best practices
- ✓ Half Nelson test
- ✓ Duct leakage to the outside test
- Finding duct leaks***
- Total system air flow



Finding Air Leaks Can Be Tricky

Or Not



A good visual inspection of a duct system will identify many air leakage locations, especially when you know where to look.

Theatrical fog injected into a duct system can assist in finding some leaks.

Using Fog

- ❑ If using a theatrical fogger with the TEC Duct Blaster system, inject the fog stream toward the edge of the fan housing and not directly into the Duct Blaster fan motor.
- ❑ Clean off any theatrical fog residue from the Duct Blaster fan motor and fan housing following the test procedure. Use only non-corrosive glycol/water-based fog.
- ❑ Do not pull smoke through the inlet side of the Retrotec model 300 fan. The fog can damage the motor.
- ❑ Discharge smoke into the flex duct then attach the fan to the duct and push smoke through system. Only use non-corrosive fog.



Fan Directed Duct Leakage Diagnostics

- ❑ The Duct Blaster fan motor is not a continuous duty motor and should not be run for extended periods of time (more than 2 hours at one time)
- ❑ The DucTester is intended for diagnostic testing and to be operated for brief periods under supervision by a qualified operator. Not to be used in a role as a household appliance for the purpose of moving air.

Duct Leakage Locations

- Joints and seams
- Boots
- Start collars, plenums, air handler and evaporator coil cabinets
- Disconnections
- Rips, holes, tears in flex duct
- Unducted platform returns

Duct Leakage Locations

- Use of building cavities – panned joists
- Poor connections between grilles, boots and interior finishes
- Poorly fitting air handler doors and filter doors
- No p-trap in the condensate line

Duct Testing & Beyond

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Definitions

System Air Flow - *The amount of air the blower fan is moving*

Duct Leakage – *The difference between the quantity of air the blower fan is moving and the amount of air being delivered into the conditioned space and returned to the air handler from the conditioned space via the duct system*

Total System Air Flow

Pressure Matching with the Duct Blaster®



TrueFlow® Grid

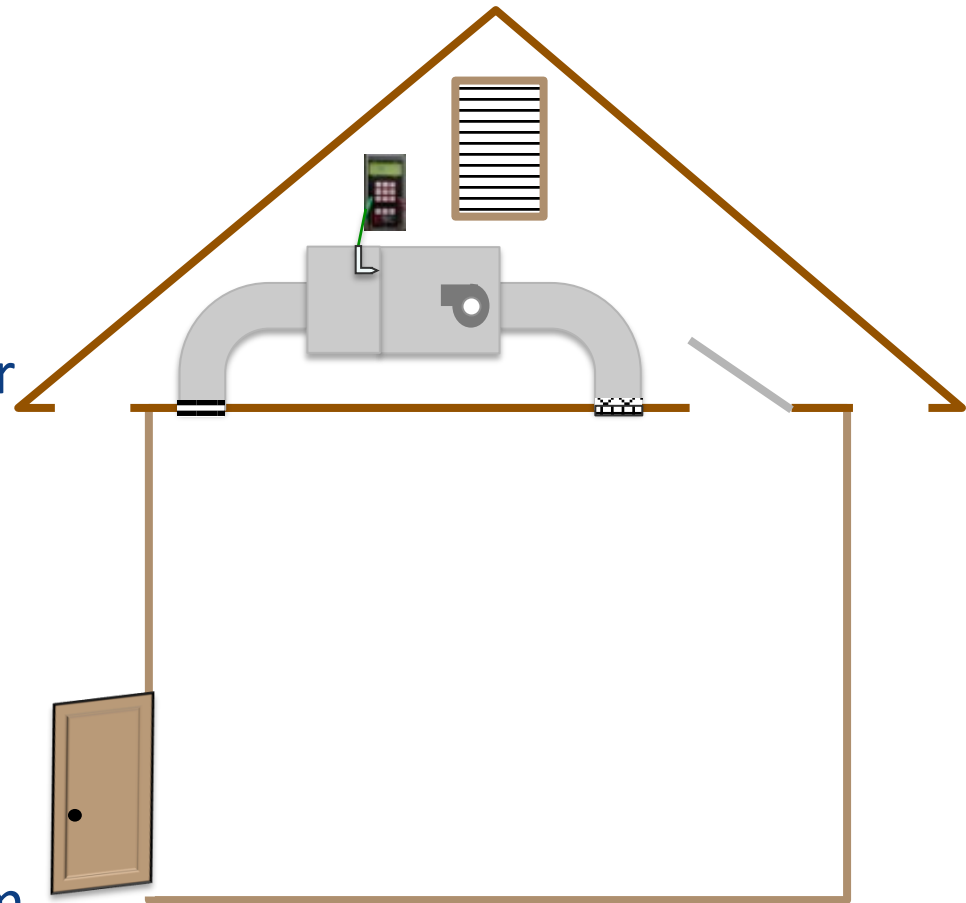


Basic Concept

- Measure Normal System Operating Pressure with manometer
- Install device
- Use duct test fan or TrueFlow pressure grid to match Normal System Operating Pressure
- Manometer can calculate the total system air flow

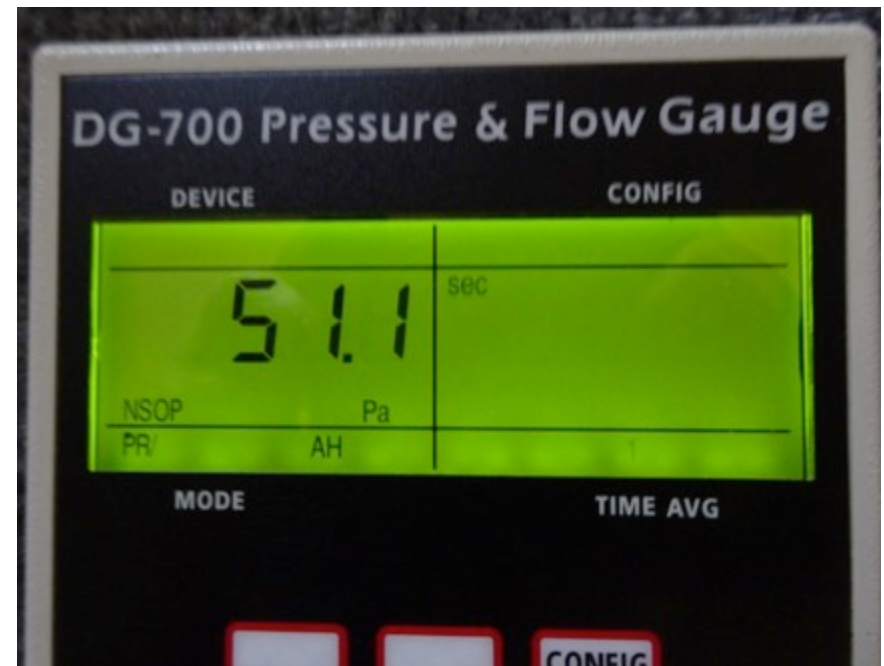
TEC Procedure for Measuring Total System Air Flow

- Begin with air handler off
- Open door or window between house and outside
- Open space where air handler is to the outside or to the house
- All supply and returns are open, they are not taped
- Filter remains in place
- Insert static pressure probe into supply plenum, pointing into the air stream

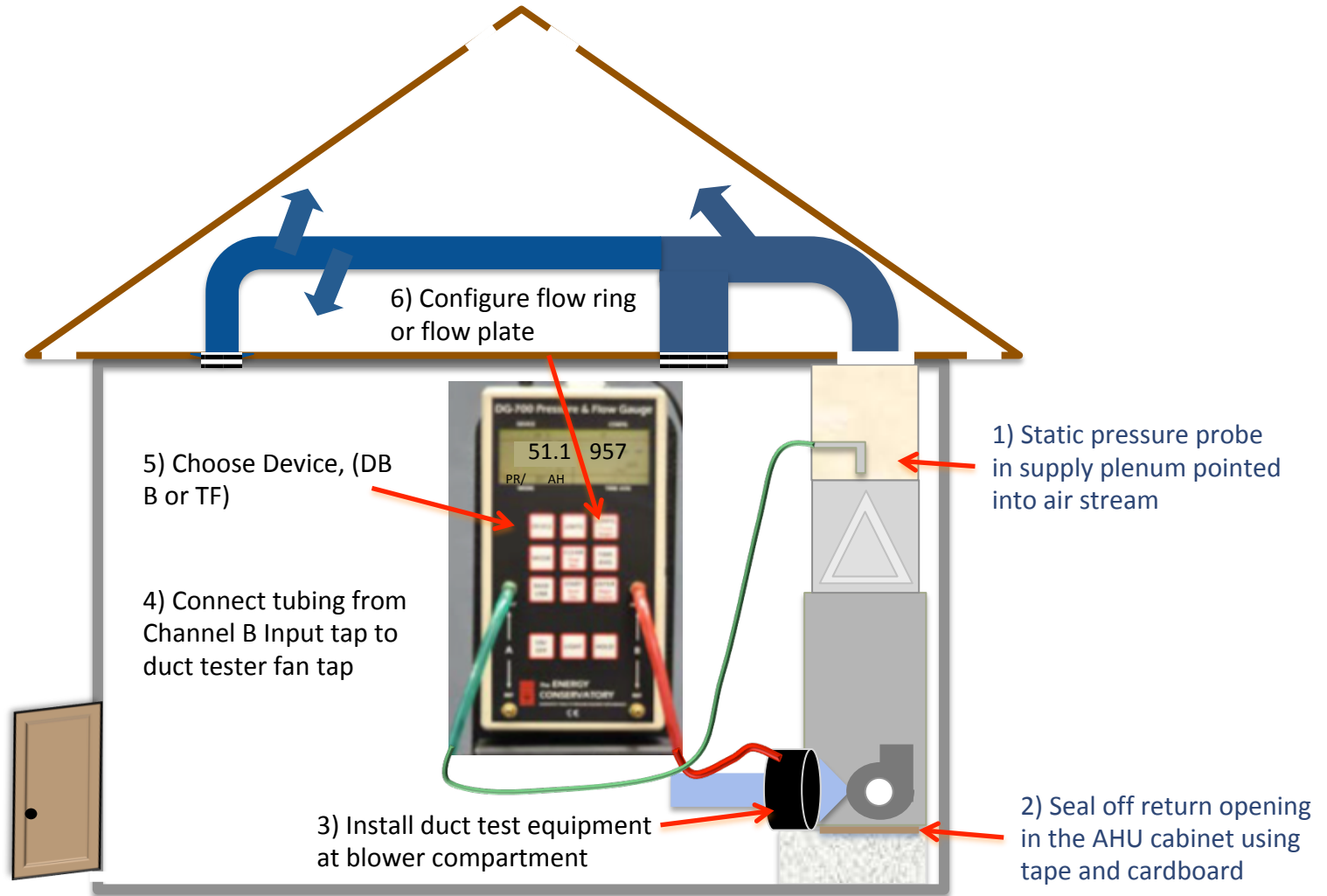


Step 1: Measure Normal System Operating Pressure (NSOP)

- Connect tubing to static pressure probe and Channel A Input tap of manometer
- Turn on the air handler to measure NSOP
 - press Start, when number stabilizes press Enter
 - Manometer has stored NSOP reading
- Turn off air handler
- Leave static pressure probe in place



Step 2: Set-up Equipment



Match Normal System Operating Pressure

- Turn the air handler fan back on
 - Channel A will display the operating duct pressure
- Turn on duct tester fan
 - Use the time average function to help stabilize the reading
- Adjust fan speed until the pressure on Channel A is within 5 Pa of the NSOP originally measured

DB B	OPEN
58.2	1568
TFSOP Pa	ADJ CFM
PR/ AH	LONG

- Total system air flow will display on Channel B



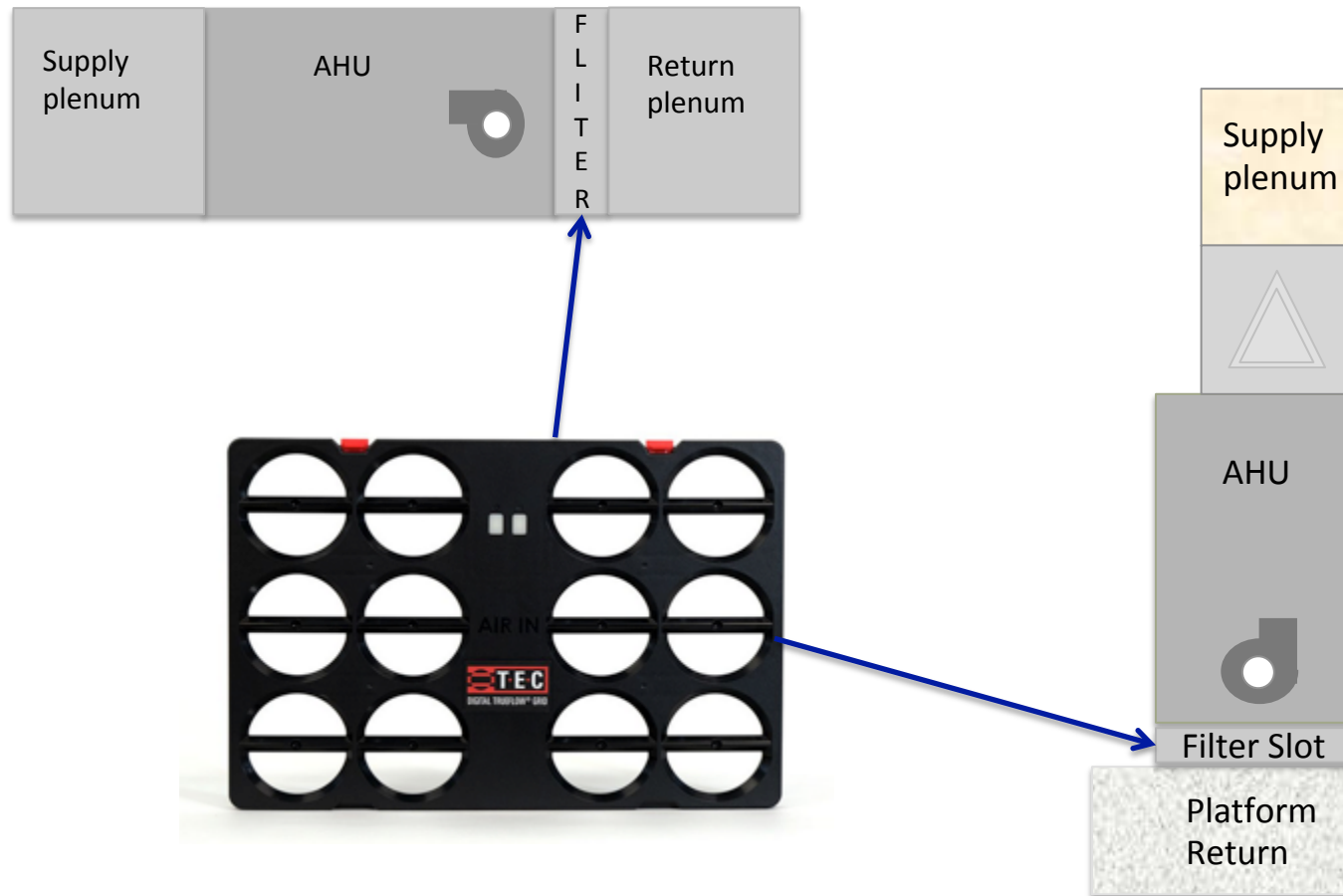
TEC TrueFlow®

Measuring Total System Air flow



When measurement is taken directly adjacent to the air handler the TrueFlow provides a fairly simple, accurate measurement of total air flow through residential air handlers rated from 1 to 5 tons

Best Locations for Total System Air Flow



Duct Testing & Beyond

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- ✓ Total system air flow

Summary

- The air flow rate through residential air handlers is an important variable for optimizing the performance of forced air heating and cooling systems
- Reduced flow rate is one of the prime reasons that HVAC systems underperform
- Air leakage in forced air duct systems is a major source of energy waste in both new and existing houses
- Duct leakage degrades indoor air quality and can cause combustion safety issues
- (IMO) Controlling duct leakage to the inside is just as important as controlling duct leakage to the outside



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