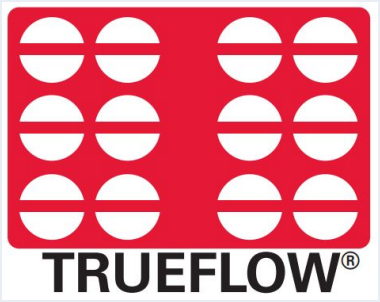
Weatherization Diagnostic Refresher



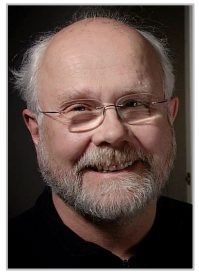
COMMUNITY ACTION PARTNERSHIP OF NORTH DAKOTA CONFERENCE

SEPTEMBER - 2022

T·E·C

Customer Technical Resources

175+ Years Experience



Gary Nelson

- Founder (40+ years)
- Physicist & Engineer from St. Olaf
- Inventor of Minneapolis Blower Door™, Ductblaster®, TrueFlow®
- Member of numerous committees (ASHRAE, RESNET, BPA)

Steve Rogers

- President, Partner
- 25+ years in pressure & flow with Emerson
- Mechanical Engineer from BYU
- One of the inventors of Digital TrueFlow®
- Member of ASME, ISO, ASHRAE committees.

Collin Olson

- Senior Staff Physicist
- 25+ years experience in building science & performance
- Ph.D. from Univ. of Wisconsin, Madison
- Member of several committees: ASHRAE 193,162, 62.2 & ABAA.

Jake McAlpine

- Technical Support Lead
- 13+ years experience in building diagnostics
- Residential Building Science Degree from Minnesota

Chris Hughes

- HVAC Business Development
- 18+ years experience as Mechanical Contractor
- Experience in air flow design, refrigeration, DDC & Pneumatic controls, VFD's, VRV/VRF Technology

Ed Janowiak

- TEC HVAC Design Consultant
- Manager of HVAC Design Education for ACCA
- 35+ years' experience in the HVAC industry

ACCA Air Conditioning Contractors of America

Bill Graber

- Marketing, Partner
- 25+ years in pressure & flow with Emerson
- Mechanical Engineer/MBA from Minnesota

T·E·C

Developing air measurement tools to help deliver better built environments

Healthy / Comfortable / Energy Efficient / Durable

AIR TIGHTNESS MEASUREMENTS

HVAC AIR MEASUREMENTS

Making it Easier to Do it Right™

T·E·C

TEC Digital Gauges over 40 years

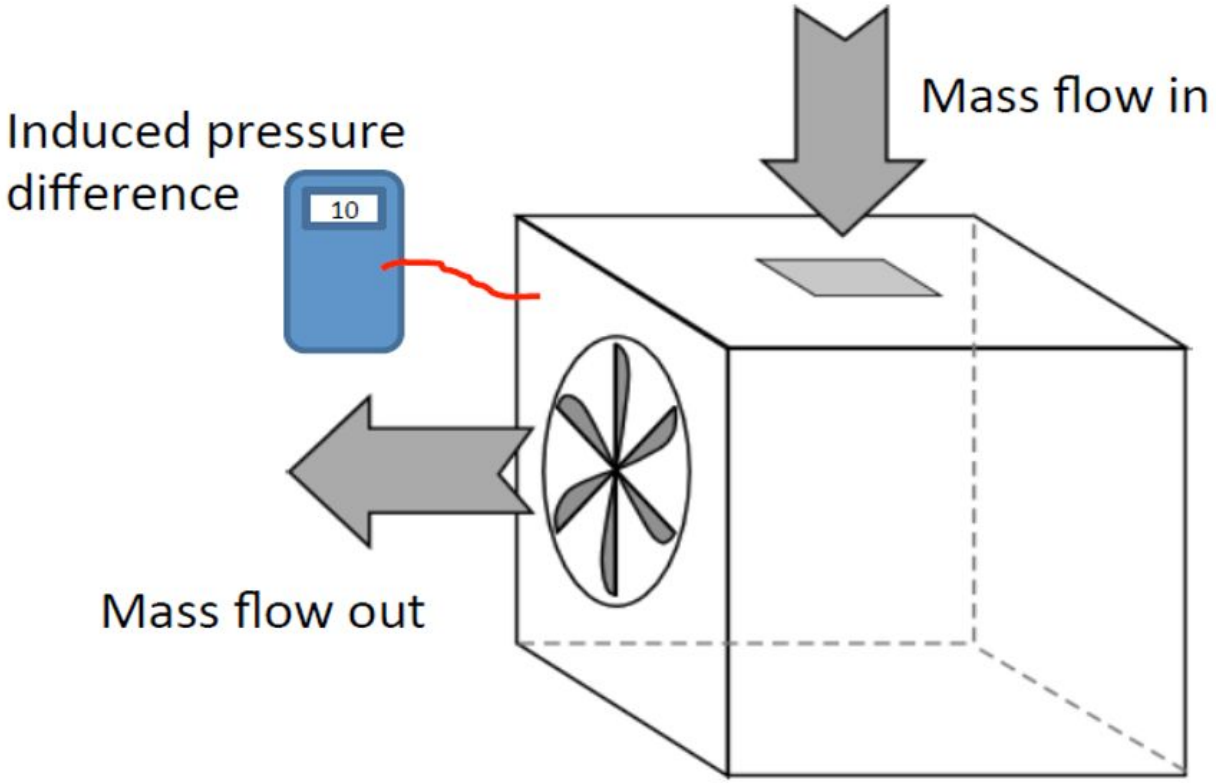
Agenda

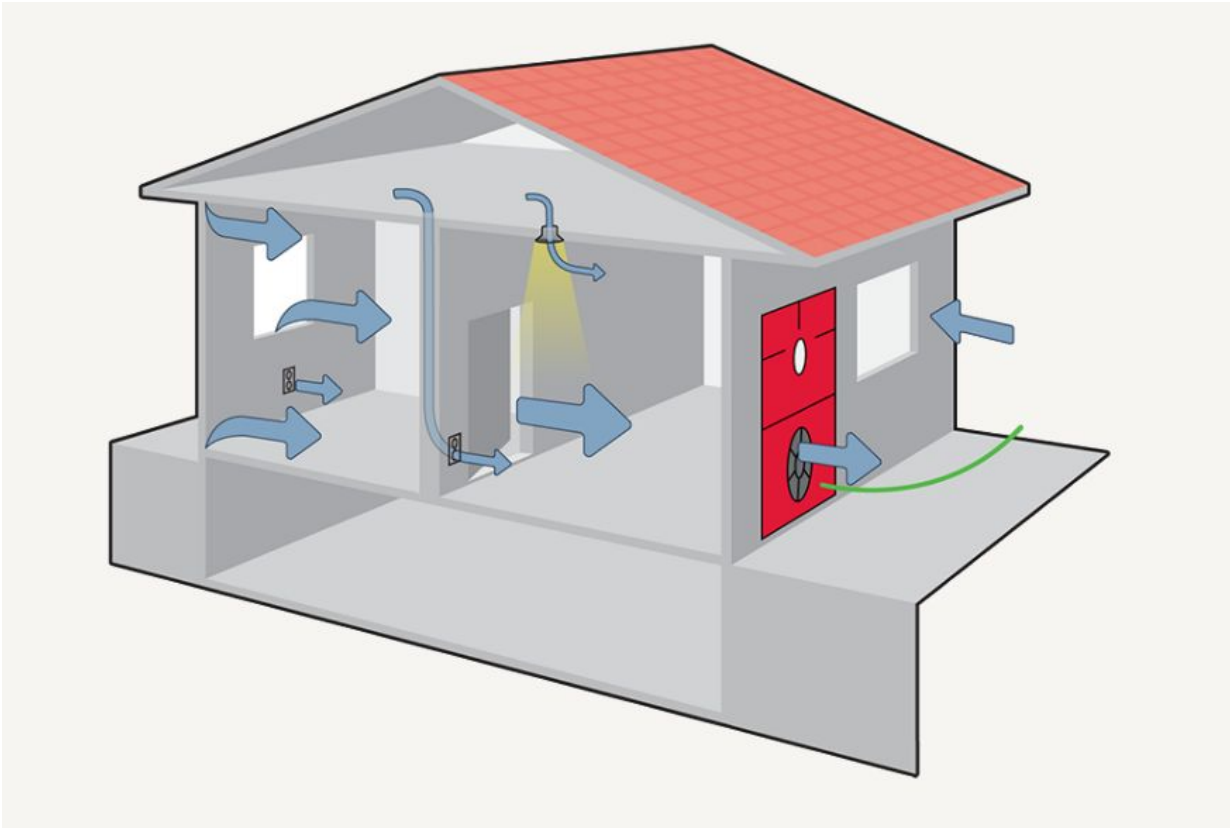
- Blower Door Testing
  - Duct leakage with pressure pan
  - Range hood pressure matching method
- Exhaust Fan Flow Meter
- Total Duct Leakage
- Leakage to the Outside
- Zone Pressure Diagnostics
  - Unmodified zone
  - Modified zone

HOW BLOWER DOORS WORK - IDEAL GAS LAW

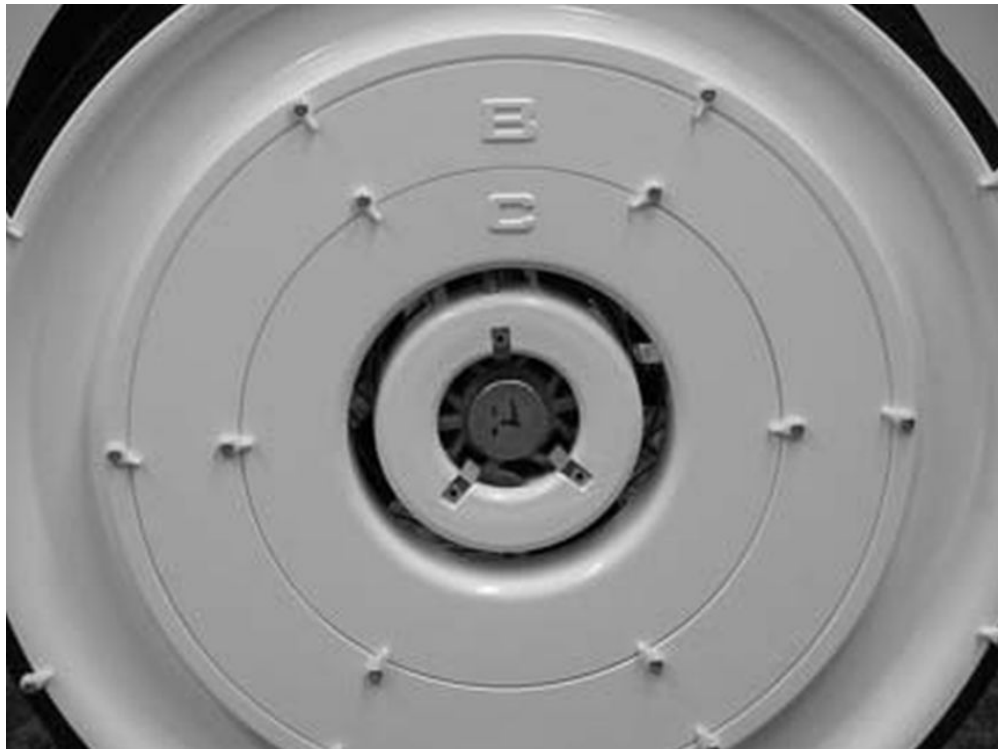
- When air is removed from a rigid structure an equal amount of air replaces it.

HOW BLOWER DOORS WORK – MASS FLOW





HOW BLOWER DOORS WORK – FLOW SENSOR



Building pressure
(test pressure)

Fan Pressure
(converted to flow)

WHY DO A BLOWER DOOR TEST?

Quantify air leakage helps:

- Reduce energy bills
- Heating system sizing
- Controlling ice dams
- Increasing comfort
- Managing moisture movement
- Understand IAQ impacts

SETTING UP THE HOUSE FOR A TEST

- Close exterior doors and windows
- Open interior doors
- Adjust all combustion appliances so they will not come on
- Turn off exhaust devices
- Turn off air handler fans (A/C only)
- Make sure fireplace/ woodstove dampers are closed
- Plumbing traps – have water in them

SETTING UP THE HOUSE FOR A TEST

- Define the tested boundaries
  - Crawlspaces
  - Attics
  - Garages
- Setting up door and vent positions
- Can anything be sealed?
  - Intentional openings
  - Window A/C

Make note of how you setup the house for repeatability

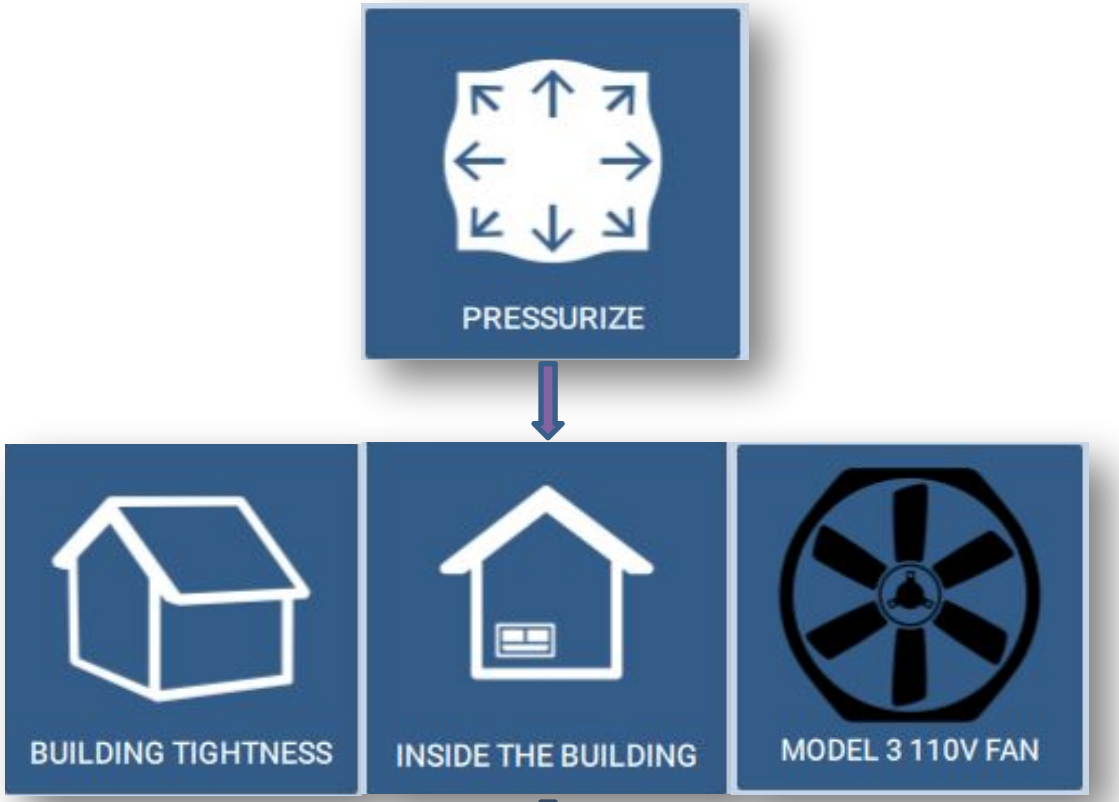
CONDUCTING A BLOWER DOOR TEST

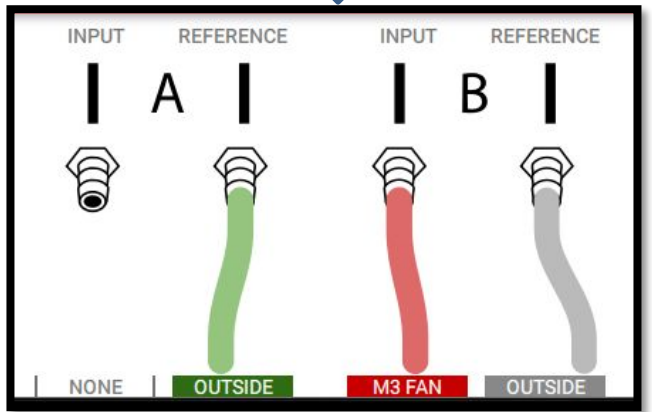
For a single point test @ 50 Pa:

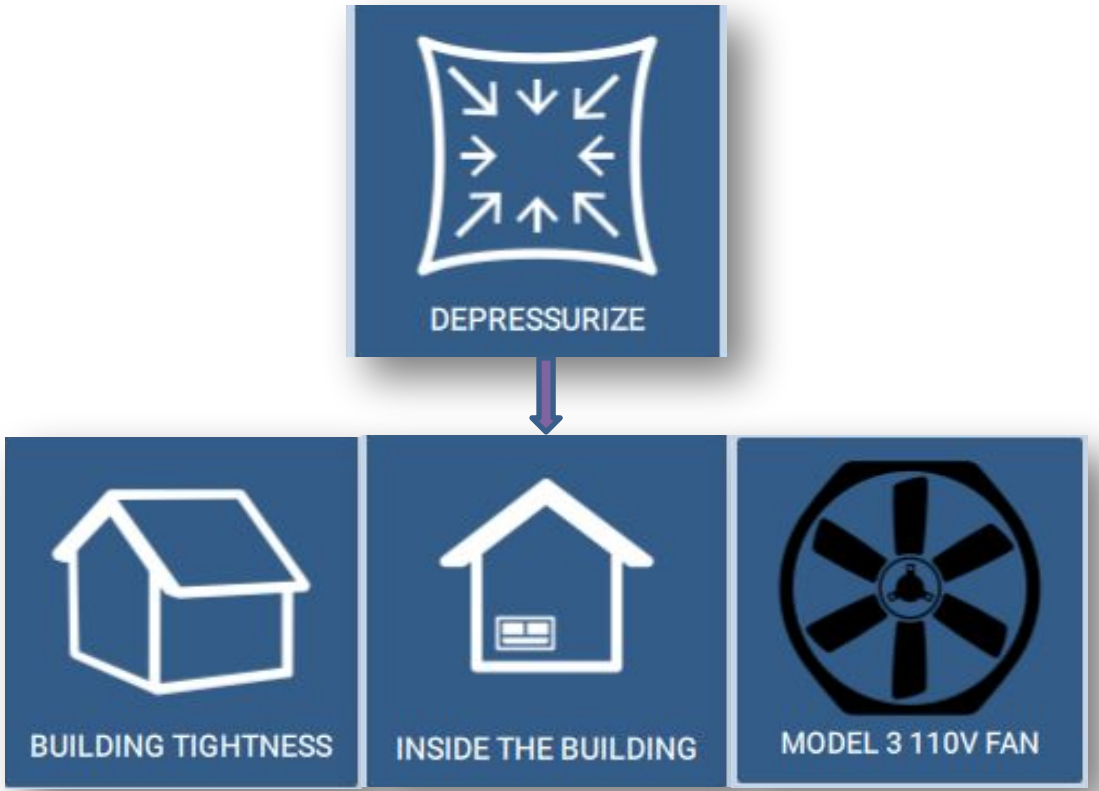
- Set up the equipment for the test
  - Pressurize or depressurize
- Set up the house for the test
- Take a baseline
- Remove rings as needed
  - Gauge and ring must be set correctly
- Change building by 50 Pa (Channel A)
- Record our leakage (Channel B)

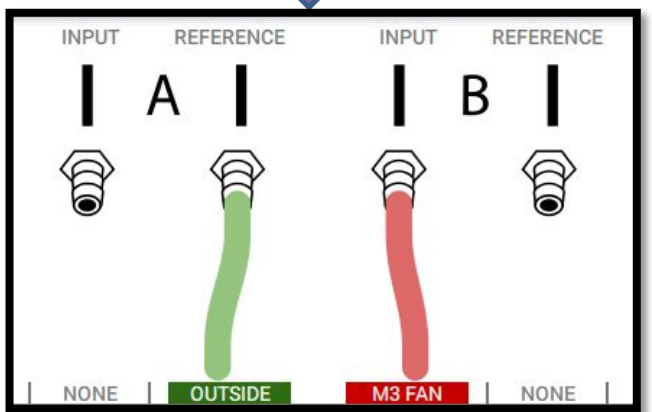
Things to add: Baseline and average final reading

Tubing Assistant Quick Guide







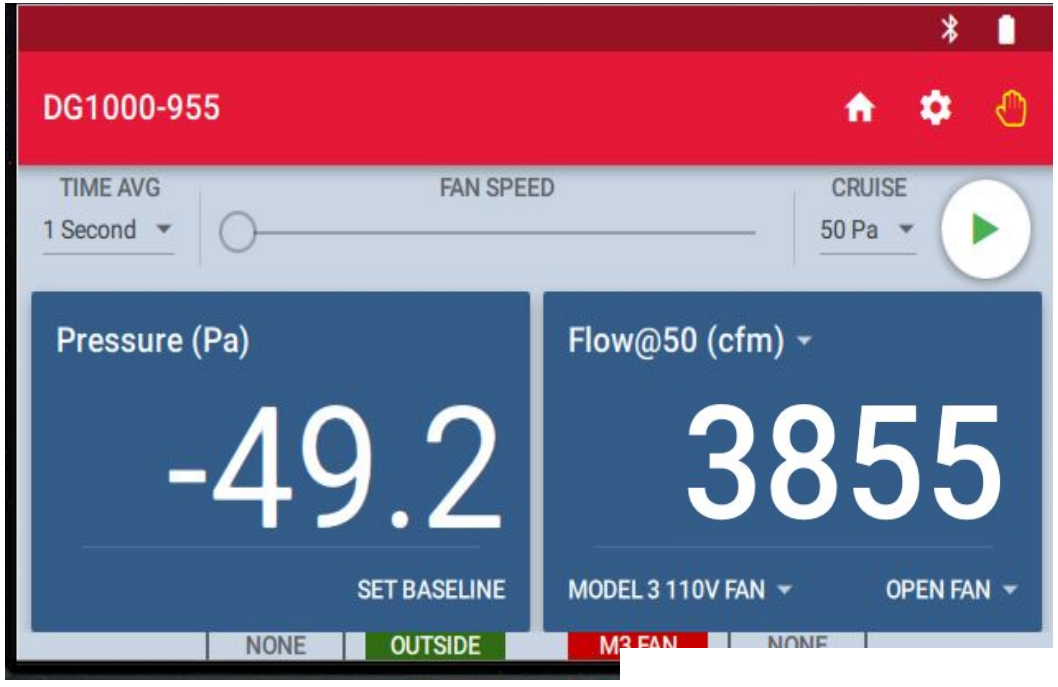


COMMON ERRORS MADE DURING A BLOWER DOOR TEST

- Not setting the house up properly
  - Windows closed and locked
  - Exterior doors/ hatches latched
  - Open doors/ hatches to conditioned spaces (attics, basements, crawlspaces)
  - Unconditioned spaces open to outside (repeatable way)

COMMON ERRORS MADE DURING A BLOWER DOOR TEST

- The ring on the fan does not match the ring setting on the gauge
- Ring A on fan, but DG-1000 is set to Open Fan



Flow (cfm)

Fan Pressure (Pa)	Open Fan	Ring A	Ring B	Ring C
64	3855	1444	476	181

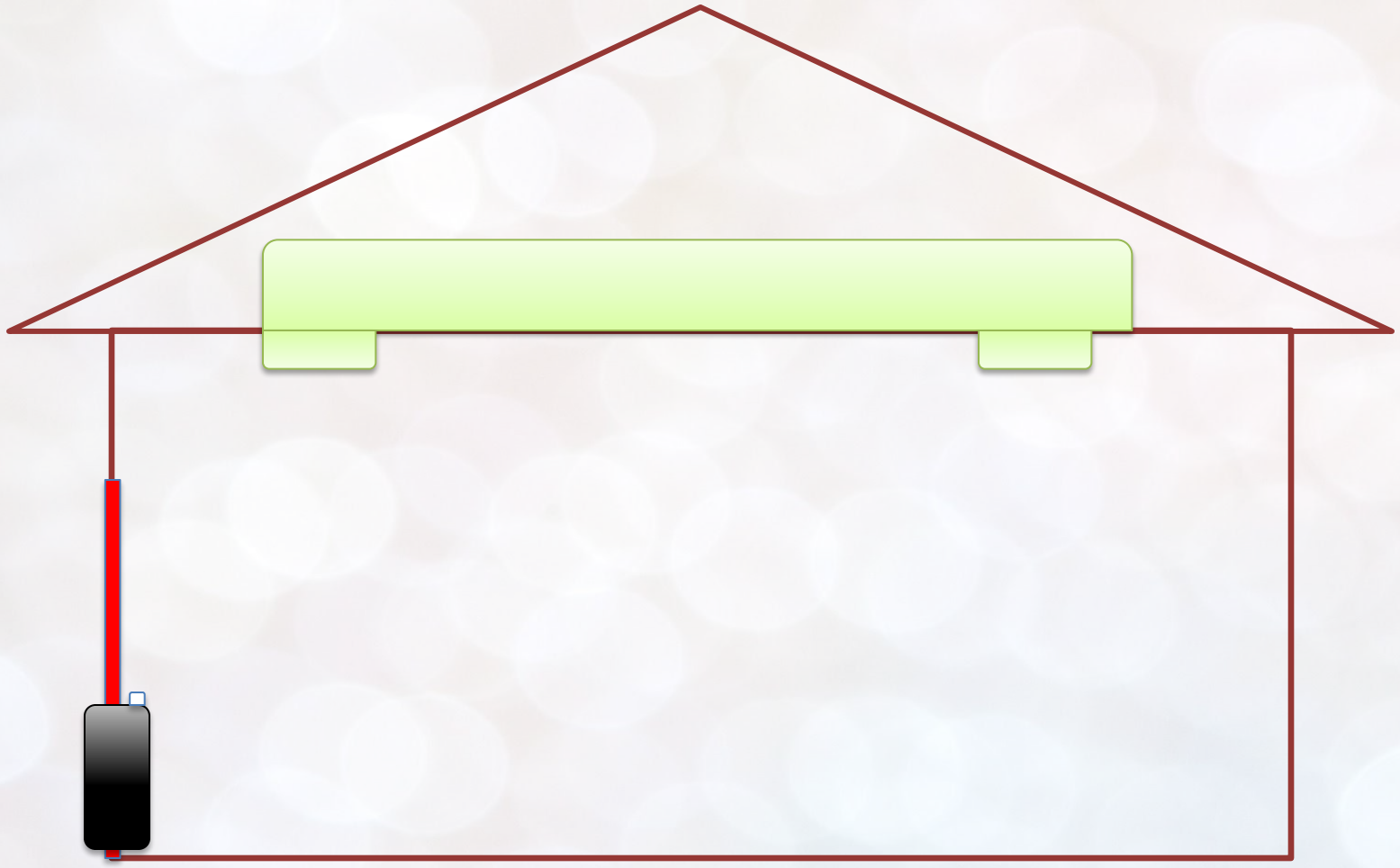
Agenda

- Blower Door Testing
  - Duct leakage with pressure pan
  - Range hood pressure matching method
- Exhaust Fan Flow Meter
- Total Duct Leakage
- Leakage to the Outside
- Zone Pressure Diagnostics
  - Unmodified zone
  - Modified zone

Duct Leakage Diagnostic – Pressure Pan

- Duct Leakage Diagnostics:
  - Pressure Pan test to determine if duct work is connected to the outside.
  - With Blower Door maintaining 50 or 25 Pa, cover registers with Pressure Pan.
  - Qualitative test.

Duct Leakage Diagnostic – Pressure Pan



Duct Leakage Diagnostic – Pressure Pan

House is
-50 pa

Duct Leakage Diagnostic – Pressure Pan

Ductwork is 100% sealed

House is -50 pa

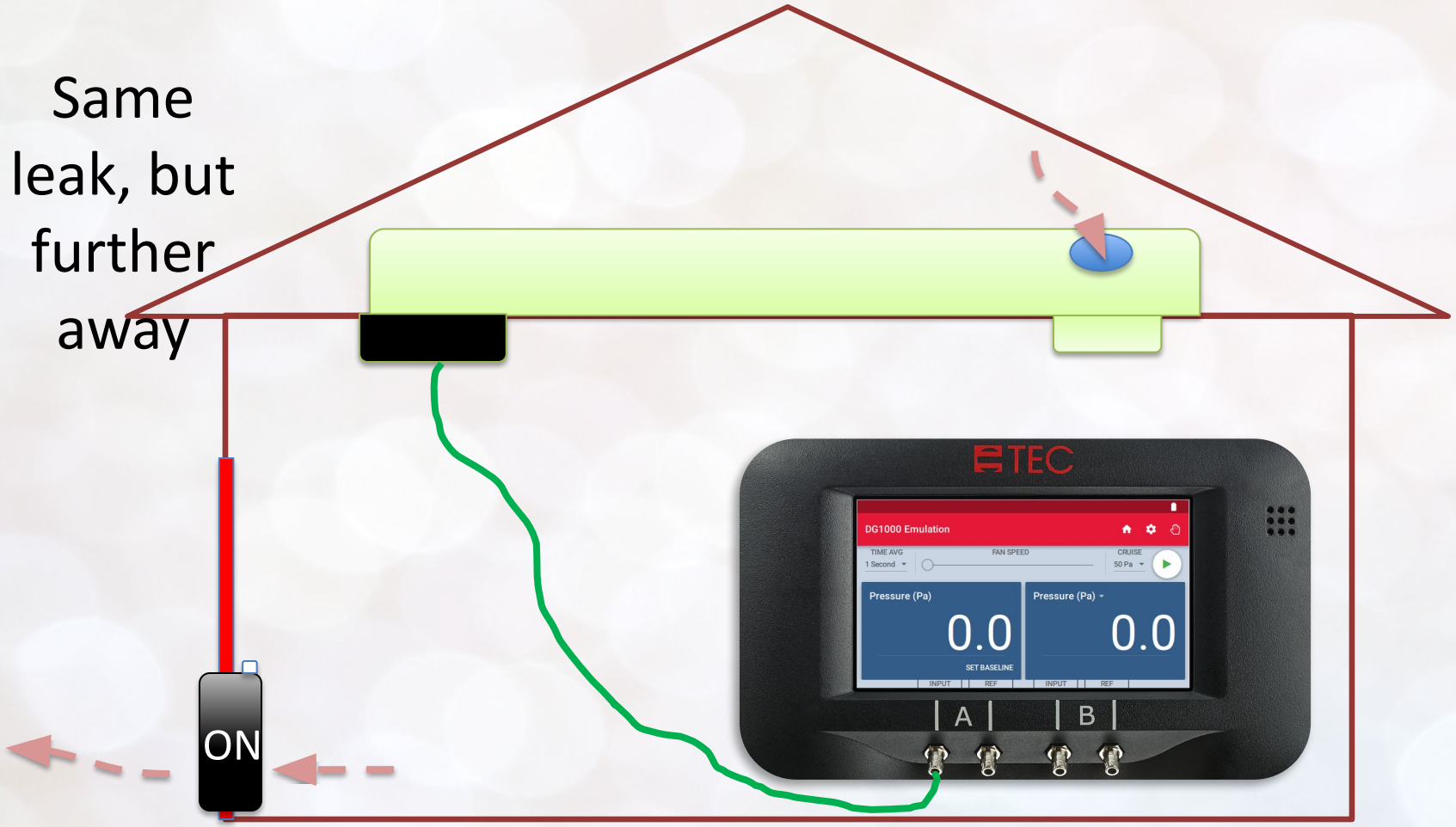
Duct Leakage Diagnostic – Pressure Pan

Ductwork has a leak

House is -50 pa

Duct Leakage Diagnostic – Pressure Pan

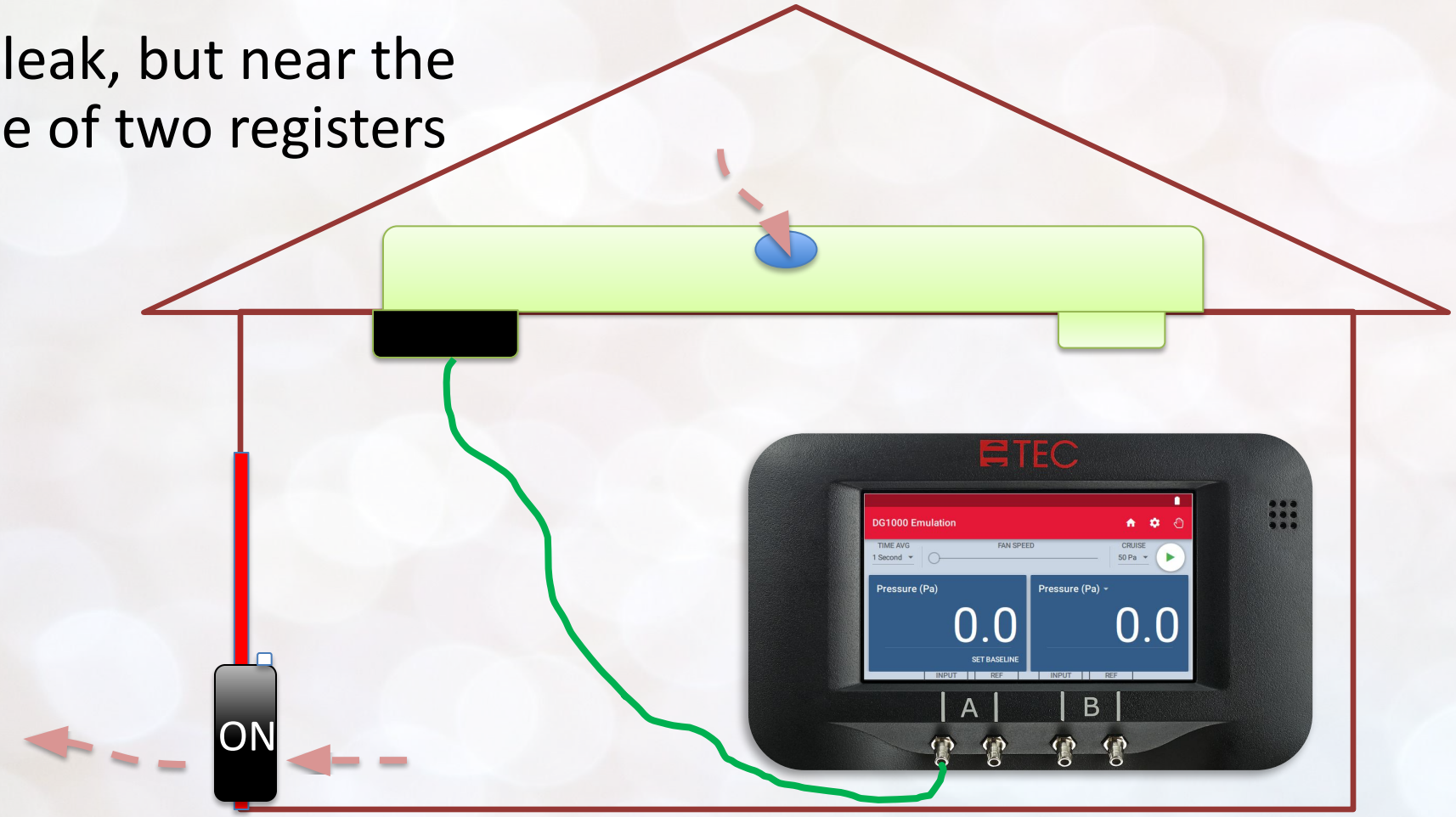
Same leak, but further away



House is -50 pa

Duct Leakage Diagnostic – Pressure Pan

Same leak, but near the middle of two registers

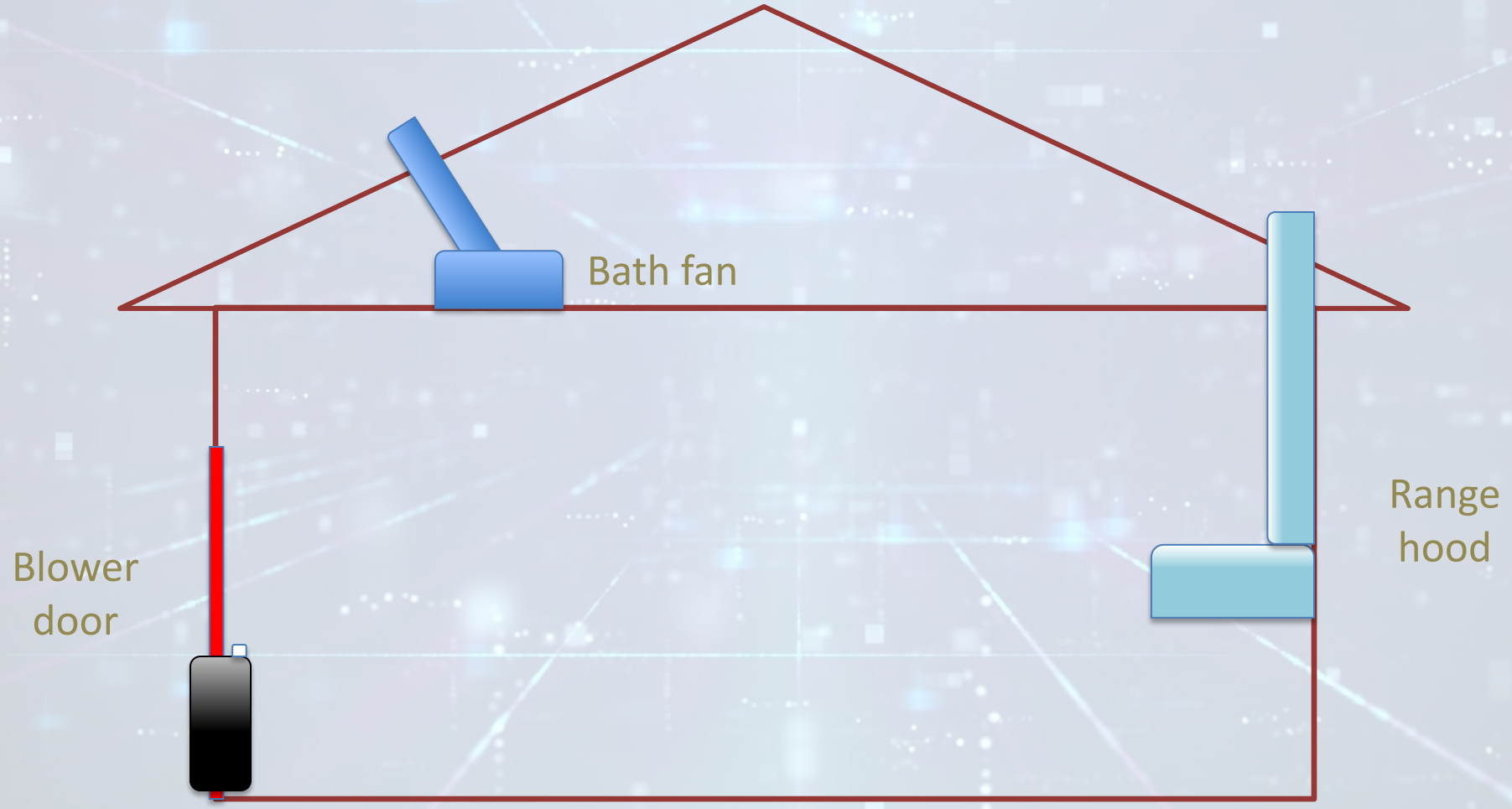


House is
-50 pa

Agenda

- Blower Door Testing
  - Duct leakage with pressure pan
  - Range hood pressure matching method
- Exhaust Fan Flow Meter
- Total Duct Leakage
- Leakage to the Outside
- Zone Pressure Diagnostics
  - Unmodified zone
  - Modified zone

Pressure Matching – Kitchen Fans



Blowe
r door

Pressure Matching – Kitchen Fans

Step 1. Take a baseline with

blower door fan capped.

Works

Pressure Matching – Kitchen Fans

Step 2. Turn on exhaust fan/s & record the pressure on Ch A.

Pressure Matching – Kitchen Fans

Step 3. Turn of fan/s & uncap

blower door fan and set to ring B

If the fan

Pressure Matching – Kitchen Fans

Step 4. Turn up blower door until you match the house pressure from step 2.

Agenda

- Blower Door Testing
  - Duct leakage with pressure pan
  - Range hood pressure matching method
- Exhaust Fan Flow Meter
- Total Duct Leakage
- Leakage to the Outside
- Zone Pressure Diagnostics
  - Unmodified zone
  - Modified zone

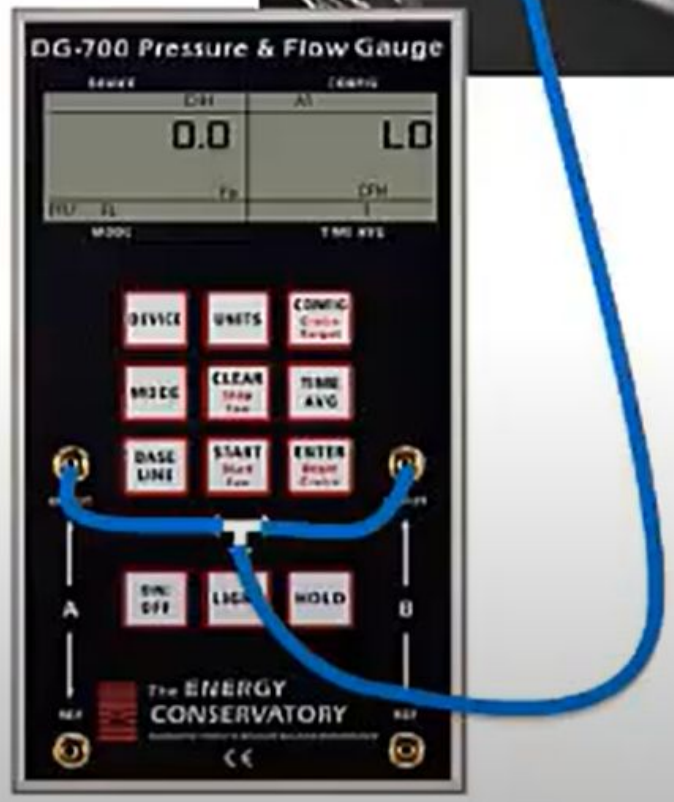
Fan Flow Measurement

- Quick accurate measurements
- Pressure gauge should have resolution of 0.1 Pa between 1 and 8 Pa.
- 10 to 124 CFM
- +/- 10% when using

Can only be used on the inlet side of a fan

Fan Flow Measurement

- Connect tubing to box

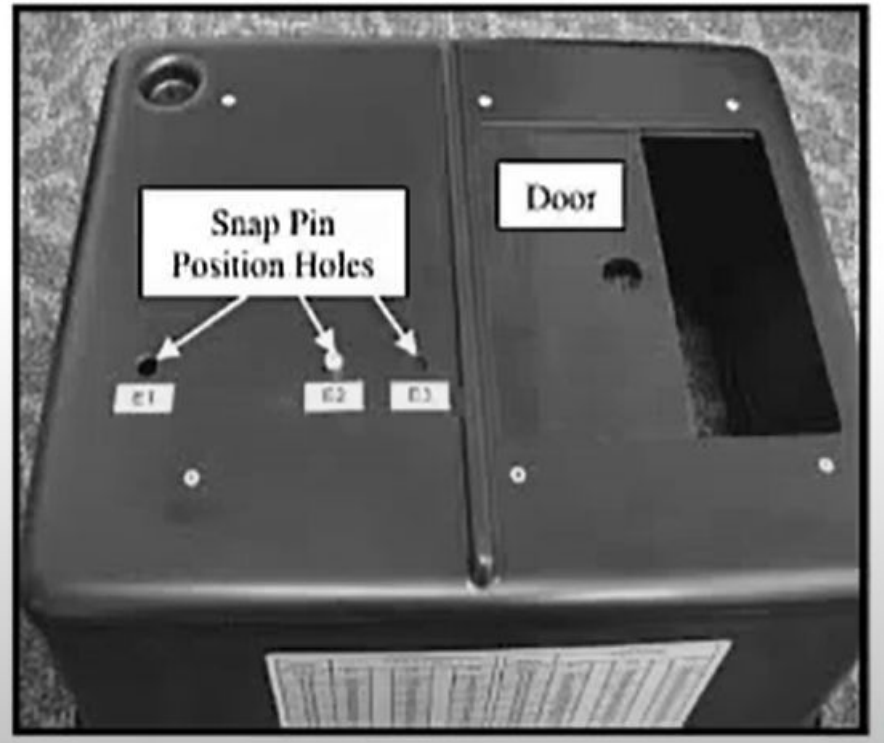


Fan Flow Measurement

- Select Door Position

Door Position	Flow Range (CFM)
E1	44 -124
E2	21 - 59
E3	10 - 28

- Pressure should be between 1 and 8 Pascals
- If not, adjust door opening
- Greater than 8 Pa, open more
- Less than 1 Pa, ("LO") close more



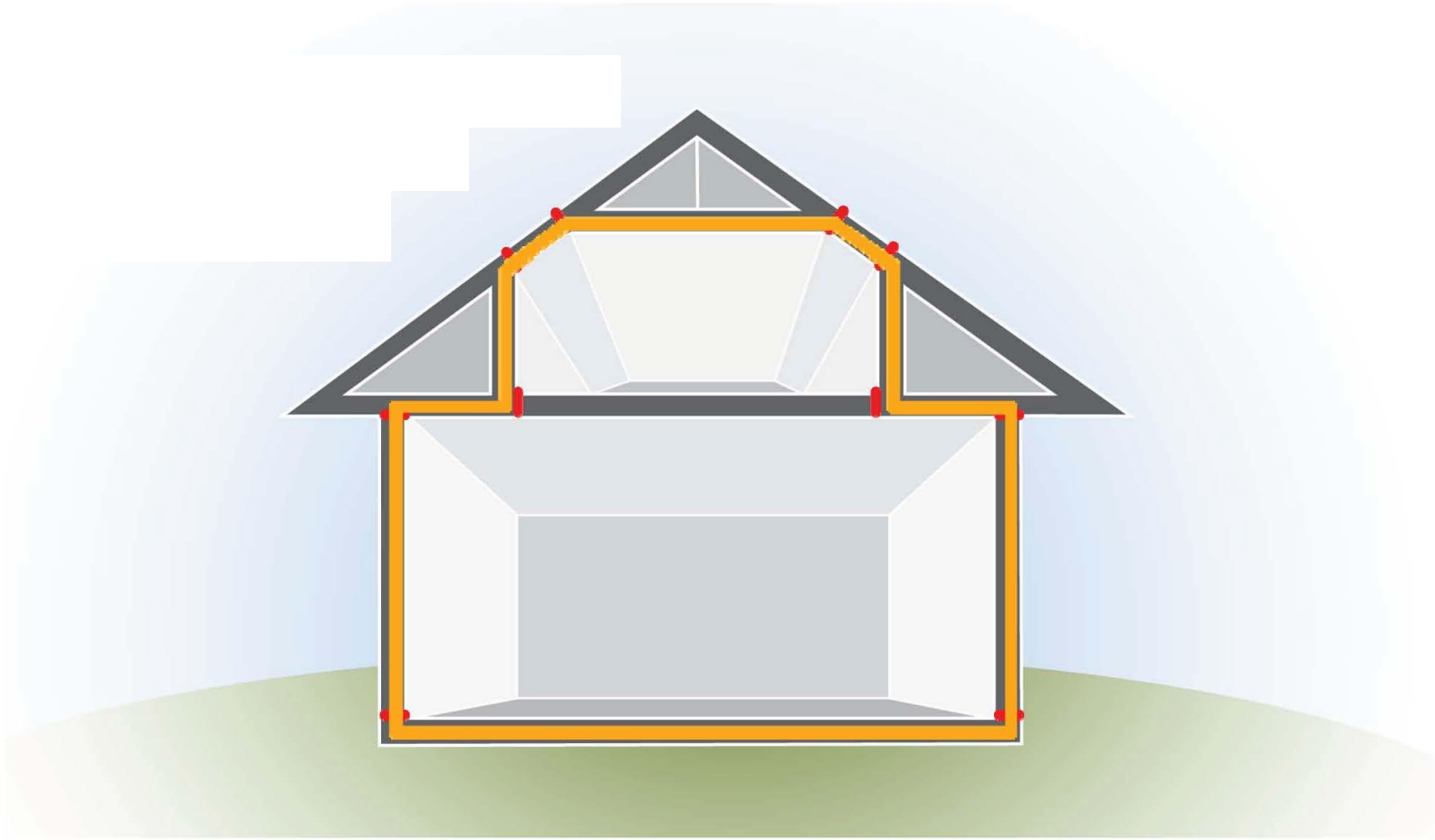
Fan Flow Measurement

- Turn on and configure gauge
- MODE = PR/ FL
- DEVICE = EXH
- CONFIG = A1, B2 or C3

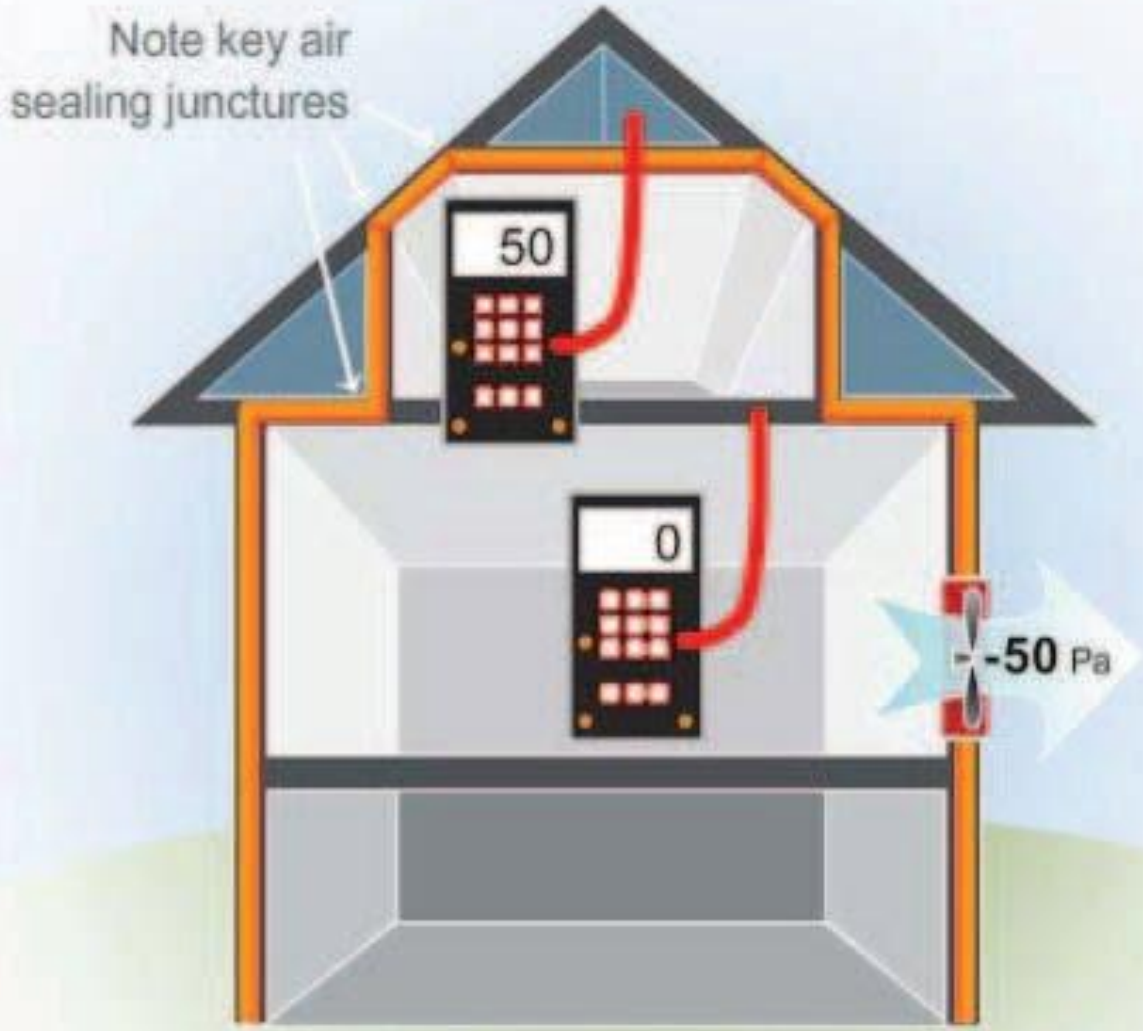
Agenda

- Blower Door Testing
  - Duct leakage with pressure pan
  - Range hood pressure matching method
- Exhaust Fan Flow Meter
- Total Duct Leakage
- Leakage to the Outside
- Zone Pressure Diagnostics
  - Unmodified zone
  - Modified zone

Where Is the Air Barrier?



Is it inside or outside?



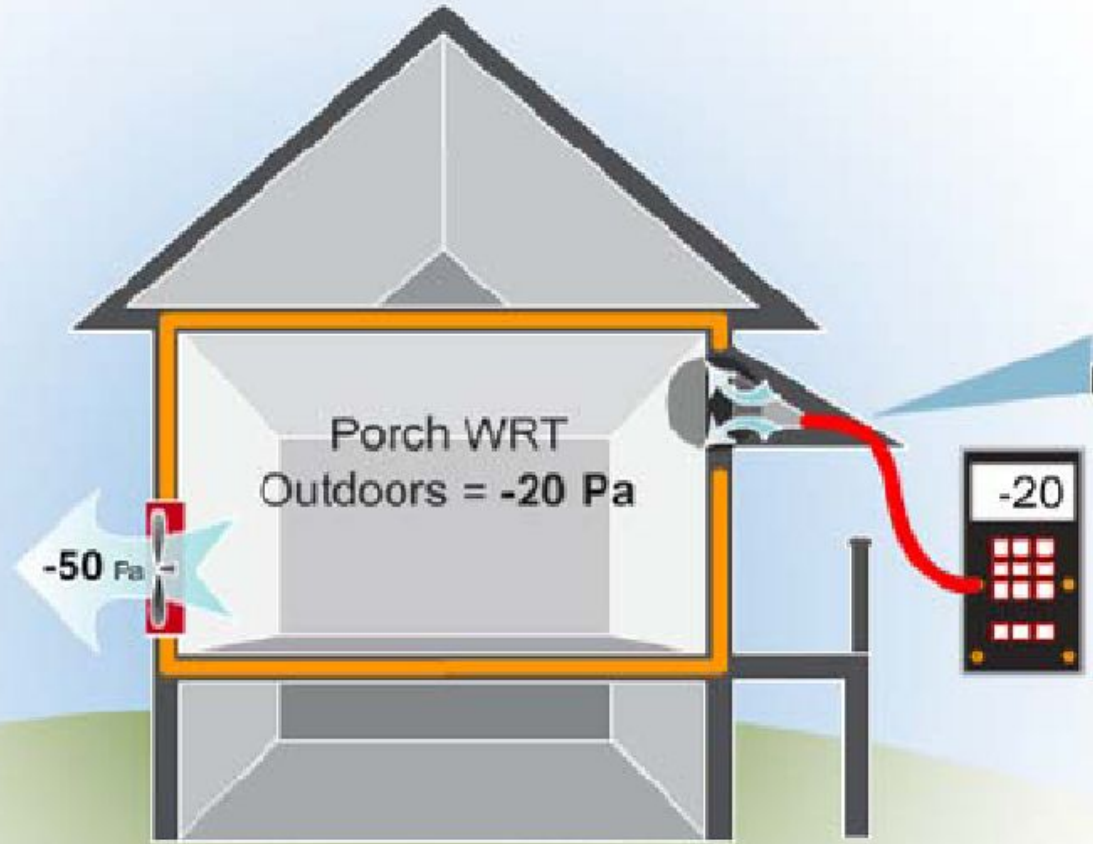
One-and-a-Half Story Cape Cod

Heated first and second floor rooms over a heated basement

☑ Air Sealed

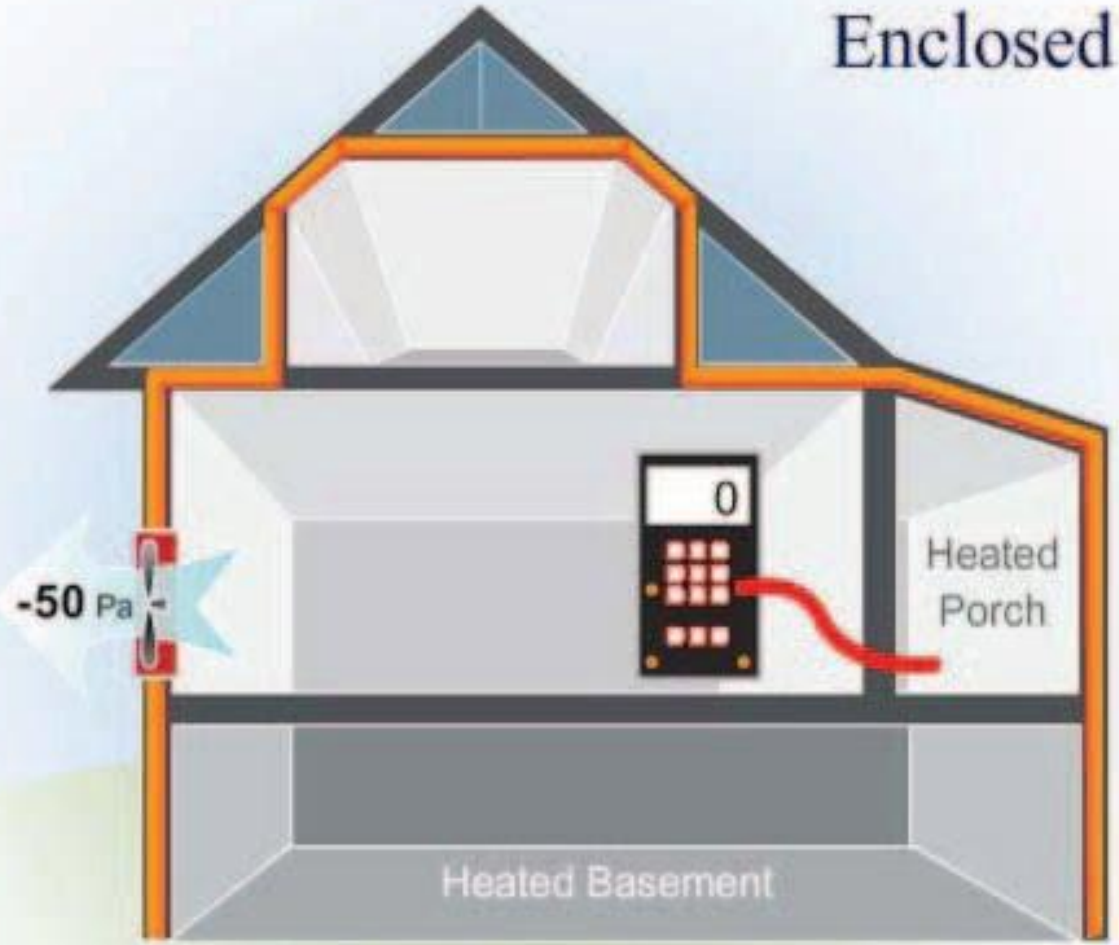
☑ Insulated

Zone Connections (Manometer Outdoors)



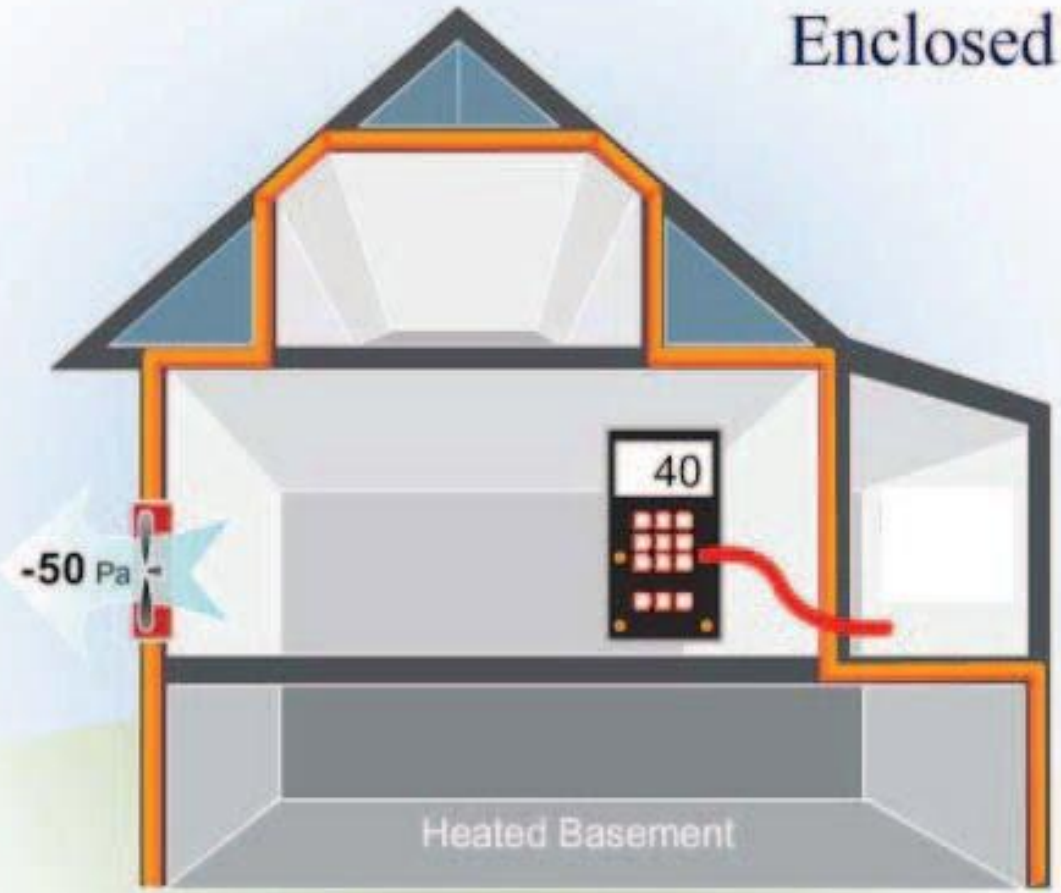
- Porch roof cavity is open to exterior wall cavities
- The goal is for the **zone WRT outdoors to be close to 0 pascals**

Enclosed Porch Strategies



Bring it in?

Enclosed Porch Strategies



Or leave it out?

Unmodified Zone

- Are pressure and thermal boundaries aligned?
  - i.e., Is pressure boundary where it is supposed to be?
- Helpful if you do not have an IR or if not enough temperature
- Helpful for inaccessible spaces

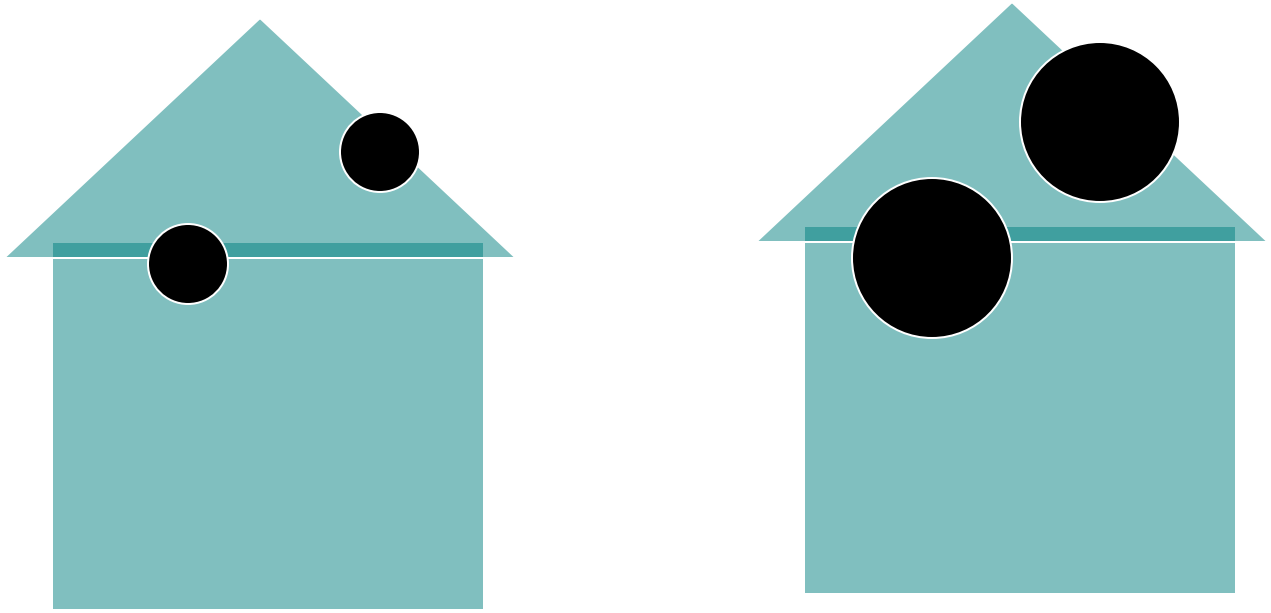
- **Does not tell you anything about how much leakage there is to that space**

Pressures and Leakage

Attic Zonal Reading of 25pa

Means hole between Attic and House is

Same size as Hole Between Attic and Outdoors

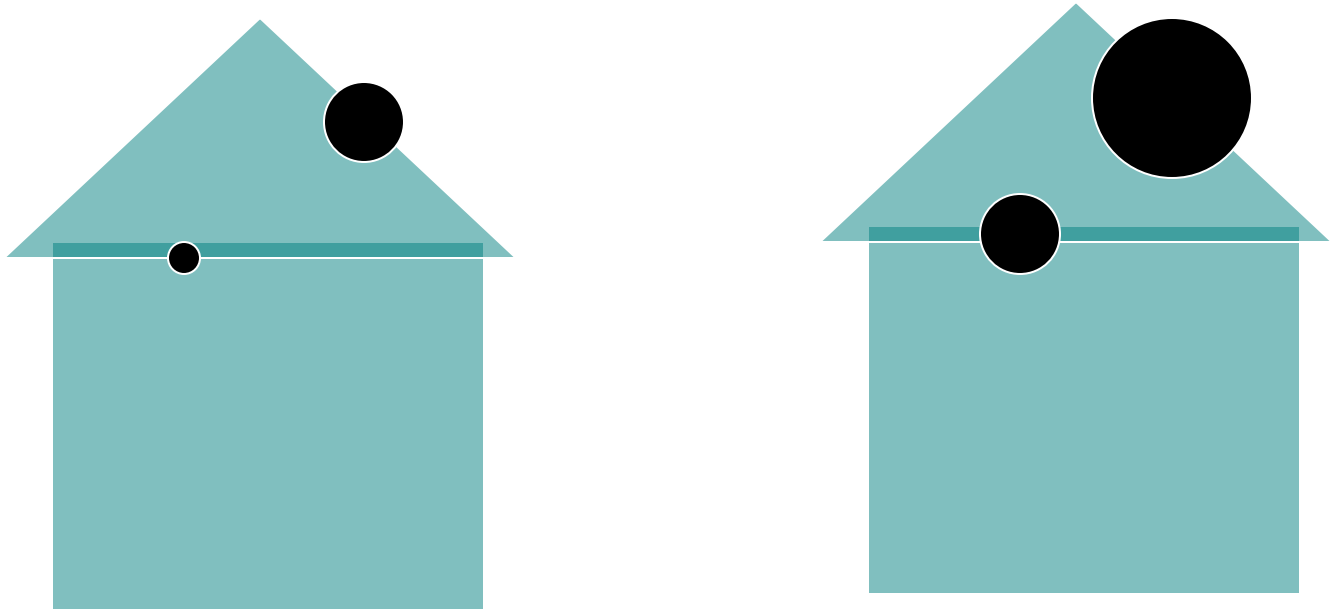


Pressures and Leakage

Attic Zonal Reading of 48pa

Means hole between Attic and House is

1/8th size of Hole Between Attic and Outdoors



Ratios of Pressures to Leakage

Zone Pressures			Relative Size of Leaks	
Zone-House	Zone-Out		Zone-House	Zone-Out
12	38		2	1
25	25		1	1
37	13		½	1
41	9		1/3	1
45	5		¼	1
48	2		1/8	1
49	1		1/13	1

Sources: Michael Blasnik and Jim Fitzgerald

T·E·C

When not to use Unmodified Zone

- Non-applicable zones
  - A single wall or floor cavity that is not likely connected to multiple other cavities.
- Not appropriate applications of ZPD
  - Using pressure pans to determine if recessed lights are leaky.
  - Measuring bedroom pressures with house at 50 pa.
  - Inferring leakiness from an unmodified zone reading alone

What is Modified Zone?

- Using software or charts to calculate cfm leakage between the house and a zone
- Requires adding a hole or opening a door house to zone or zone to outside
- It will tell how much air is leaking into and out of the zone!
  - Makes a whole whole blower door more specific
  - Great way to set air sealing targets and understand the building

How to use Modified Zone test

- Record baseline adjusted measurements H/Z and Z/O and cfm50 of the house
- Open a door or add a hole H/Z or Z/O and return house to 50 pa.
- Record new measurements H/Z and Z/O and cfm50 of the house
- Use software or charts to calculate leakage areas

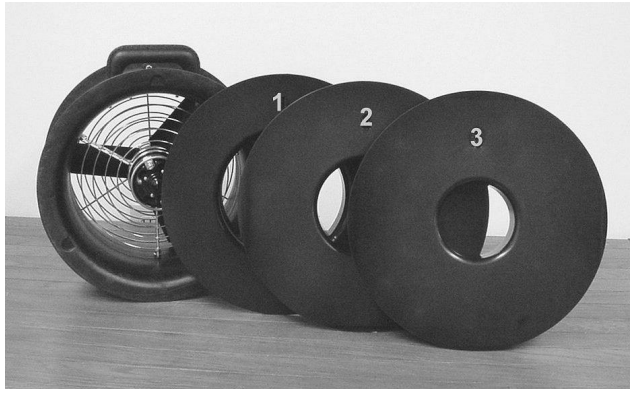
Use of Modified Zone Pressure test to Guide Air Sealing

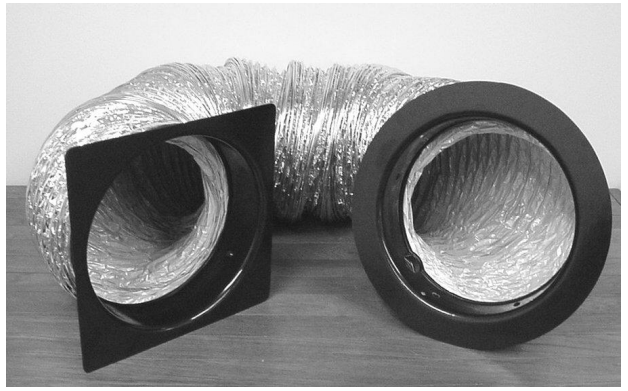
Actions Taken	Blower Door		ZPD – through zone		Comments
	Test In (CFM50)	Test Out (CFM50)	Test In (CFM50)	Test Out (CFM50)	
Fix big leaks in Attic	2056	1292	1200	478	37% reduction of air leaks in entire home
Fix smaller leaks in Attic	1292	1047	478	370	Additional 12% reduction
Fix other leaks	1047	937	370	210	Additional reduction 6%. Total air leakage reduction 55%

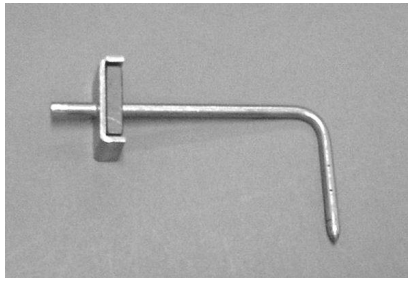
Agenda

- Blower Door Testing
  - Duct leakage with pressure pan
  - Range hood pressure matching method
- Exhaust Fan Flow Meter
- Total Duct Leakage
- Leakage to the Outside
- Zone Pressure Diagnostics
  - Unmodified zone
  - Modified zone

DUCT TESTING SYSTEM COMPONENTS

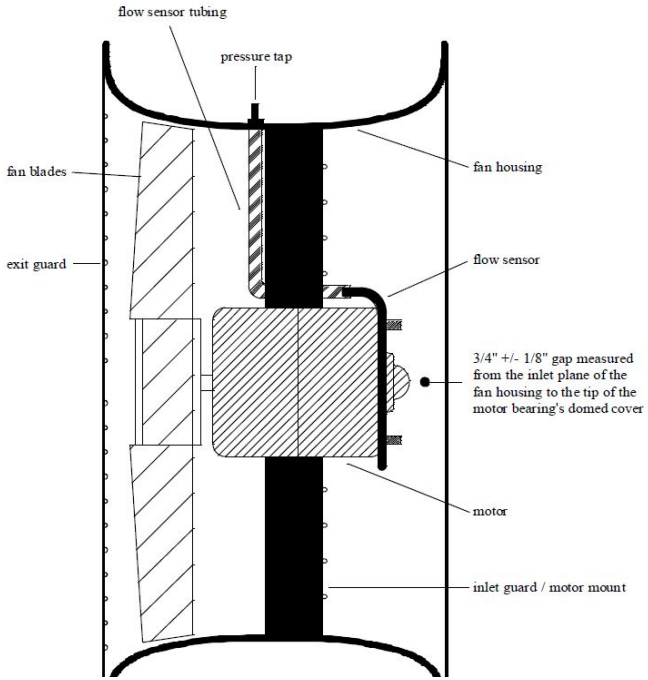






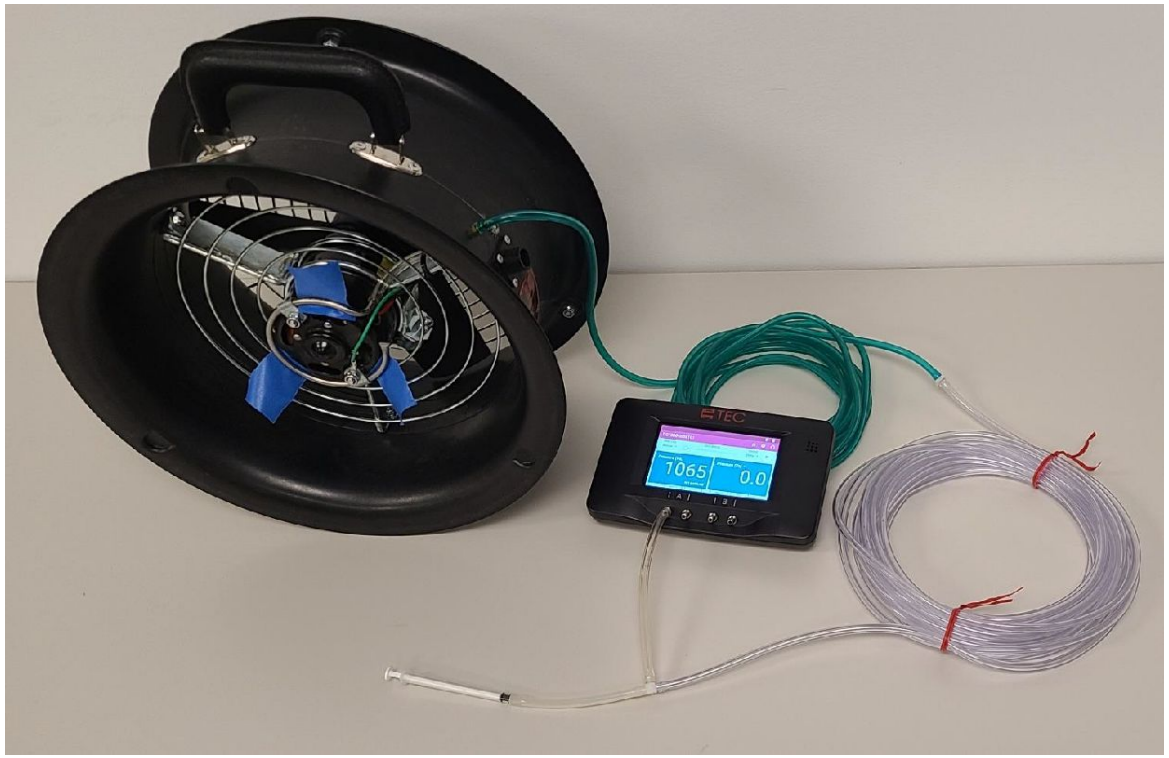
CALIBRATION OF EQUIPMENT

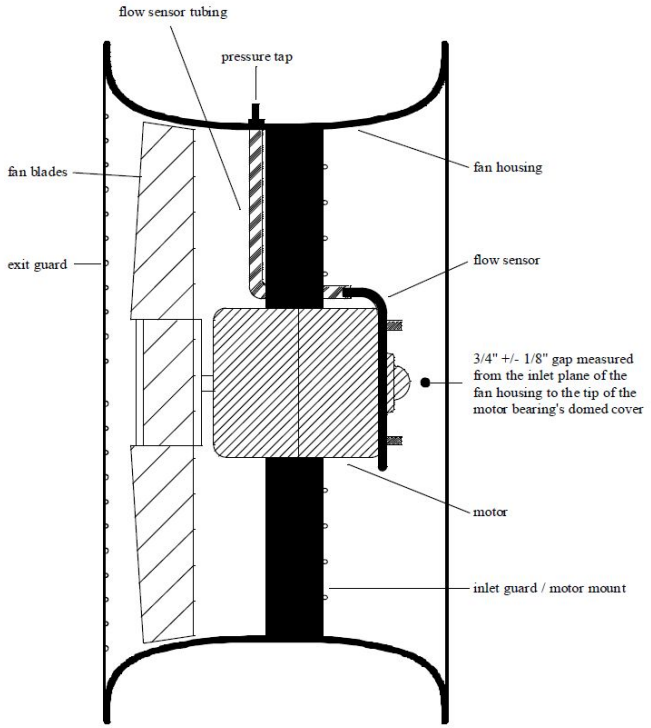
- Gauges and Fans
- Factory calibration vs Field calibration check



CALIBRATION OF EQUIPMENT

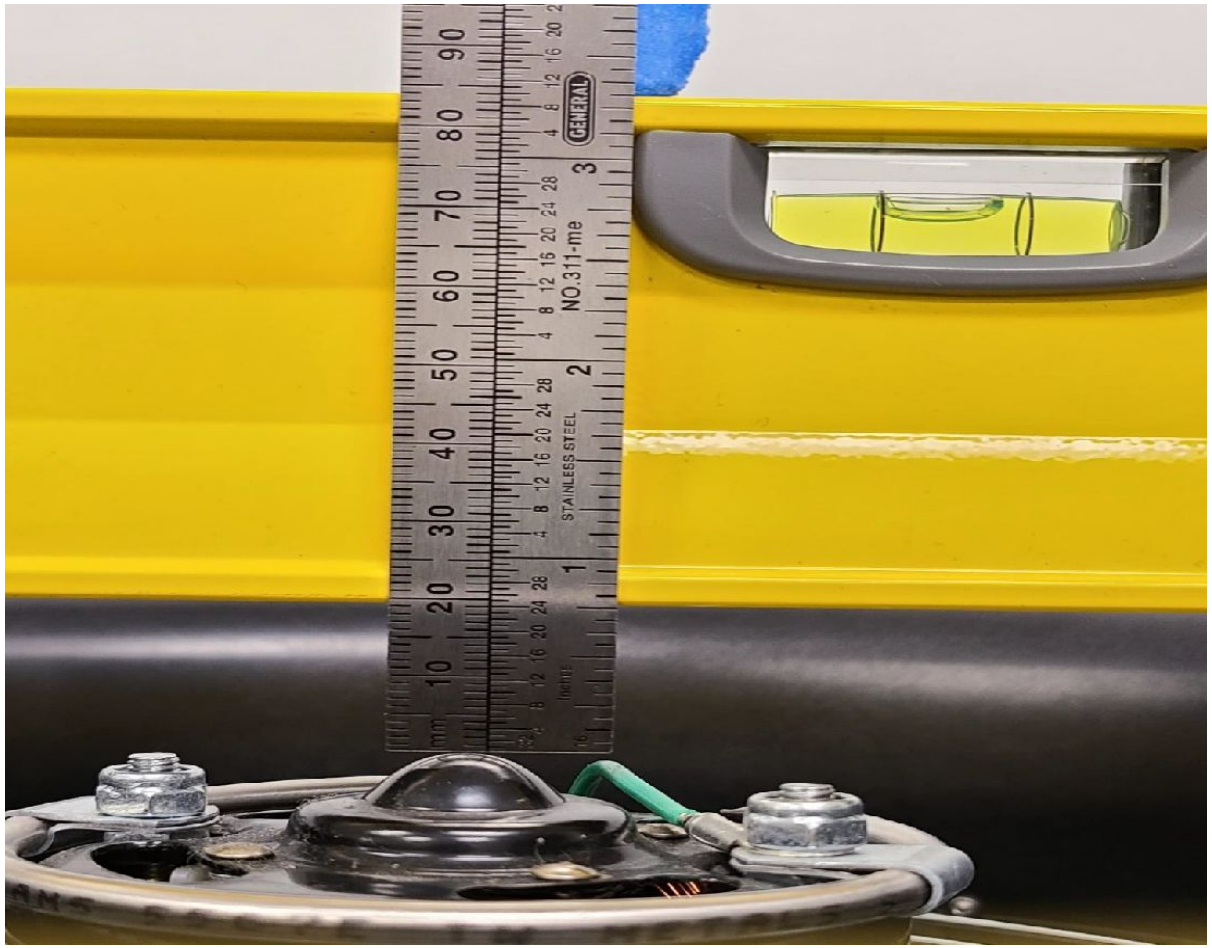
- Duct Blaster





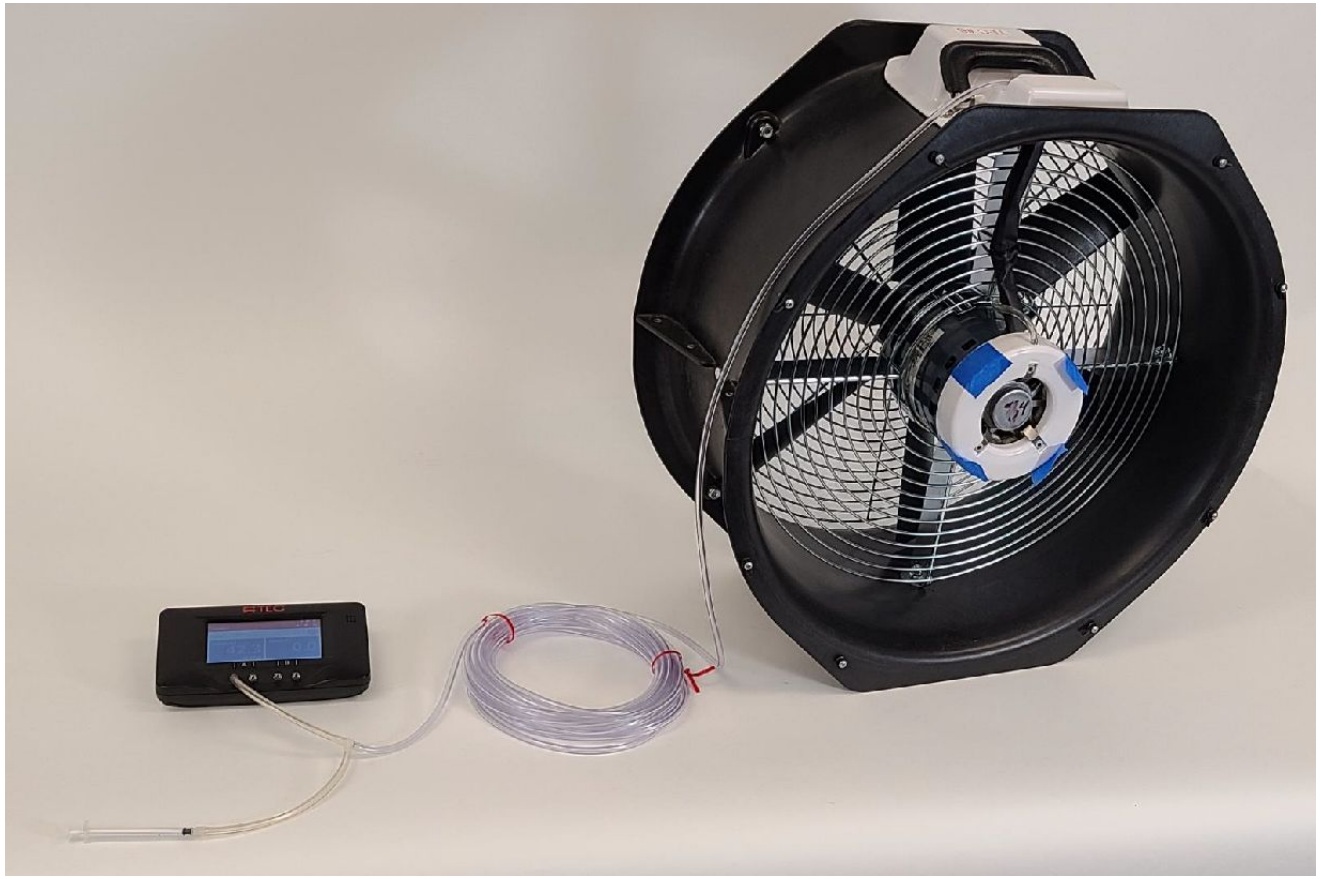
CALIBRATION OF EQUIPMENT

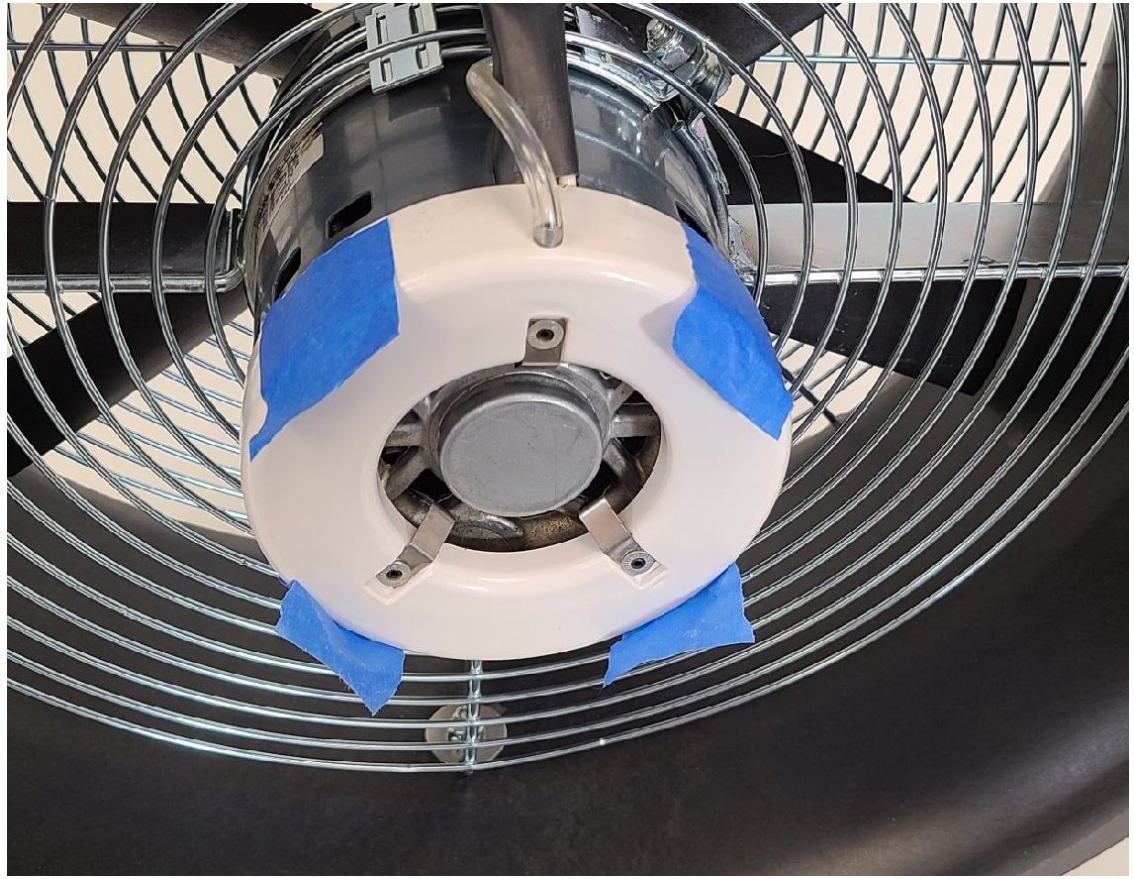
- Duct Blaster



CALIBRATION OF EQUIPMENT

- Blower Door



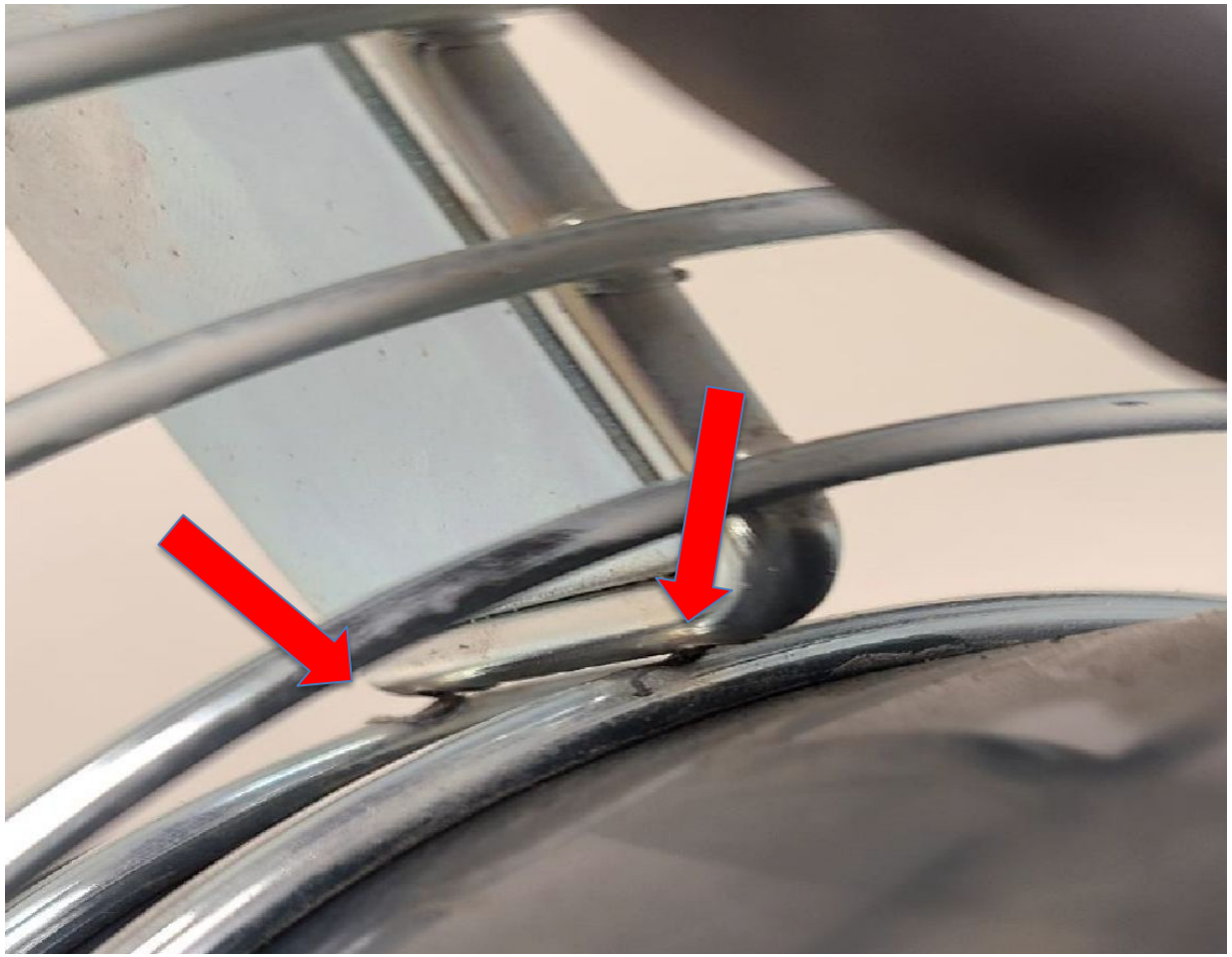


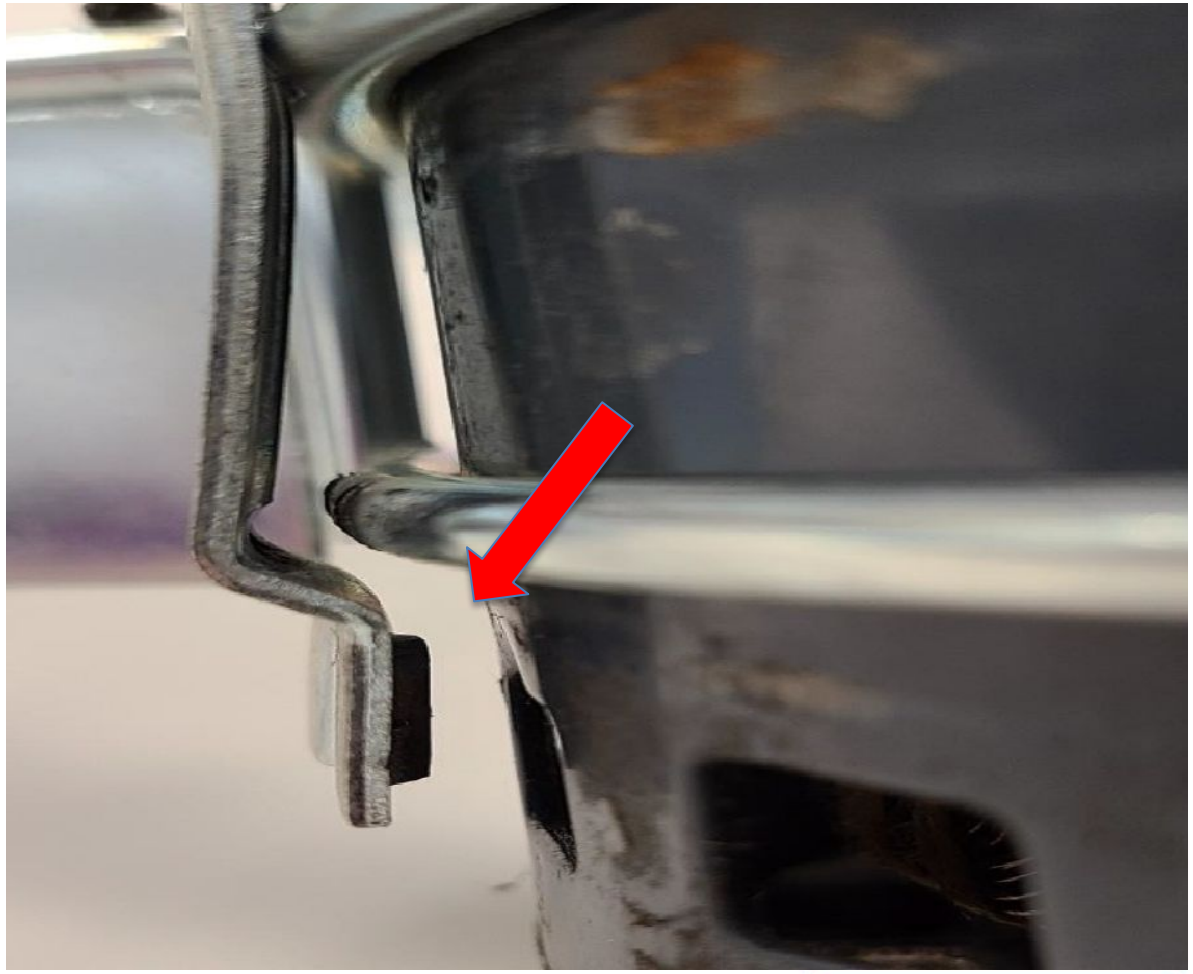
CALIBRATION OF EQUIPMENT

- Blower Door

CALIBRATION OF EQUIPMENT

- Blower Door





TEST SETUP: BUILDING & DUCTS

Prepare the building or dwelling unit

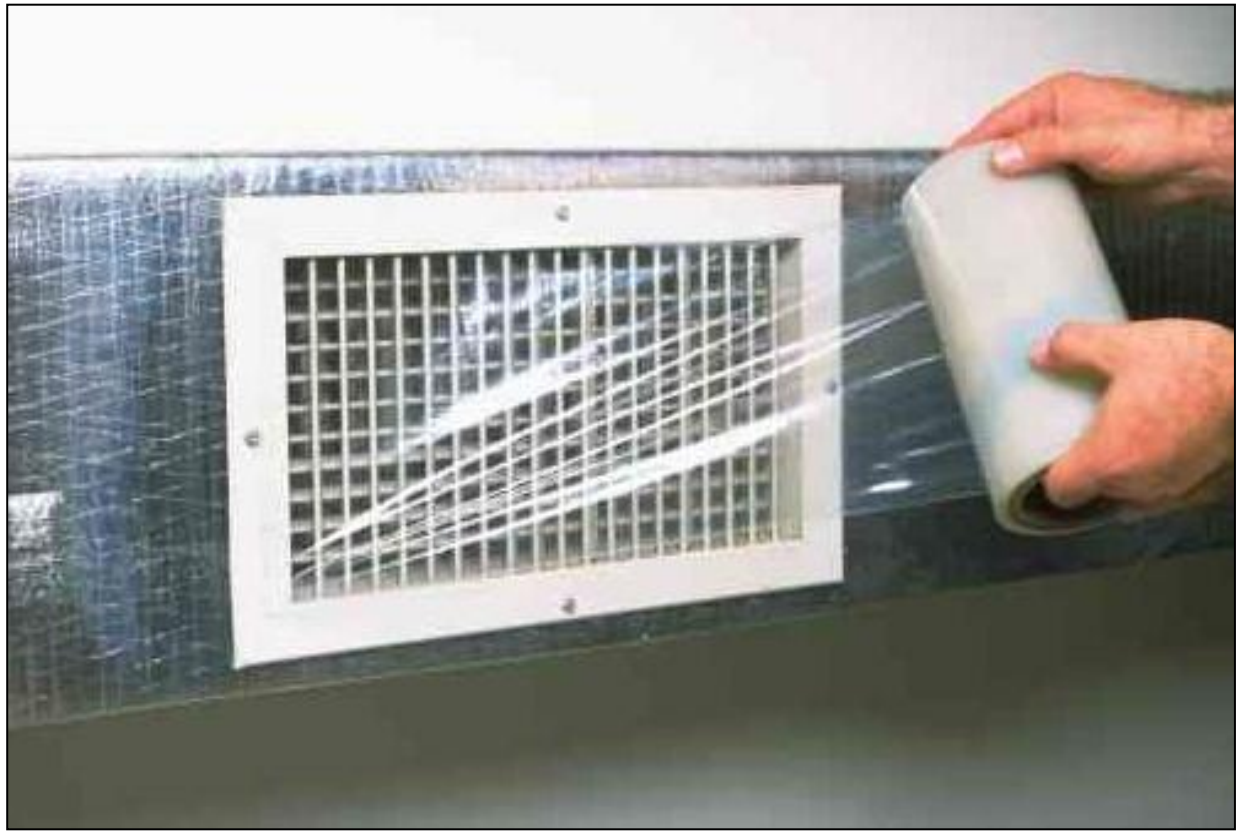
- Turn off the air handler and remove filters
- Turn off:
  - vented combustion appliances
  - exhaust devices

Prepare the Duct System

- Dampers in a duct system:
  - Leave non-motorized dampers as is
  - Open motorized zone dampers
  - Close motorized outdoor air dampers
- Non-dampered ventilation openings:
  - Consult your standard or program
    - Intermittent ventilation systems – do not seal
    - Continuous ventilations systems – seal

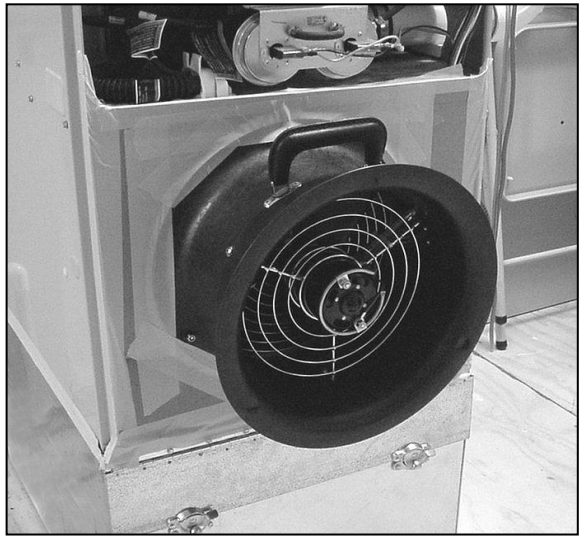
TEST SETUP: PREPARE THE DUCTWORK

- Seal over all registers and grilles at face and perimeter
- Registers over carpet can be sealed at the duct boot
- Total leakage Test – this makes a difference
- DLTO – may not matter due to house pressure matching

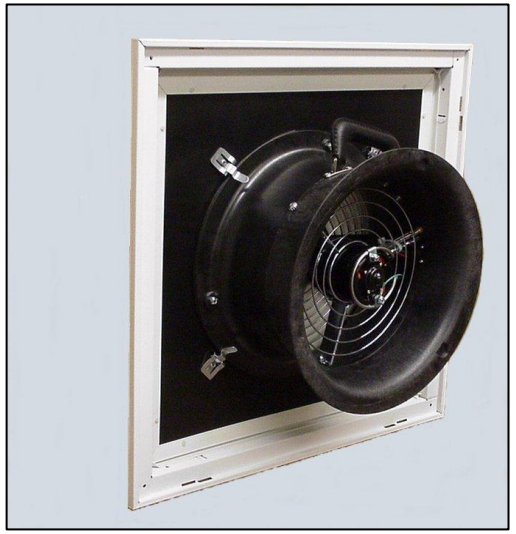


TEST SETUP: CONNECTING THE FAN

- More than 3 returns:
  connect at air handler

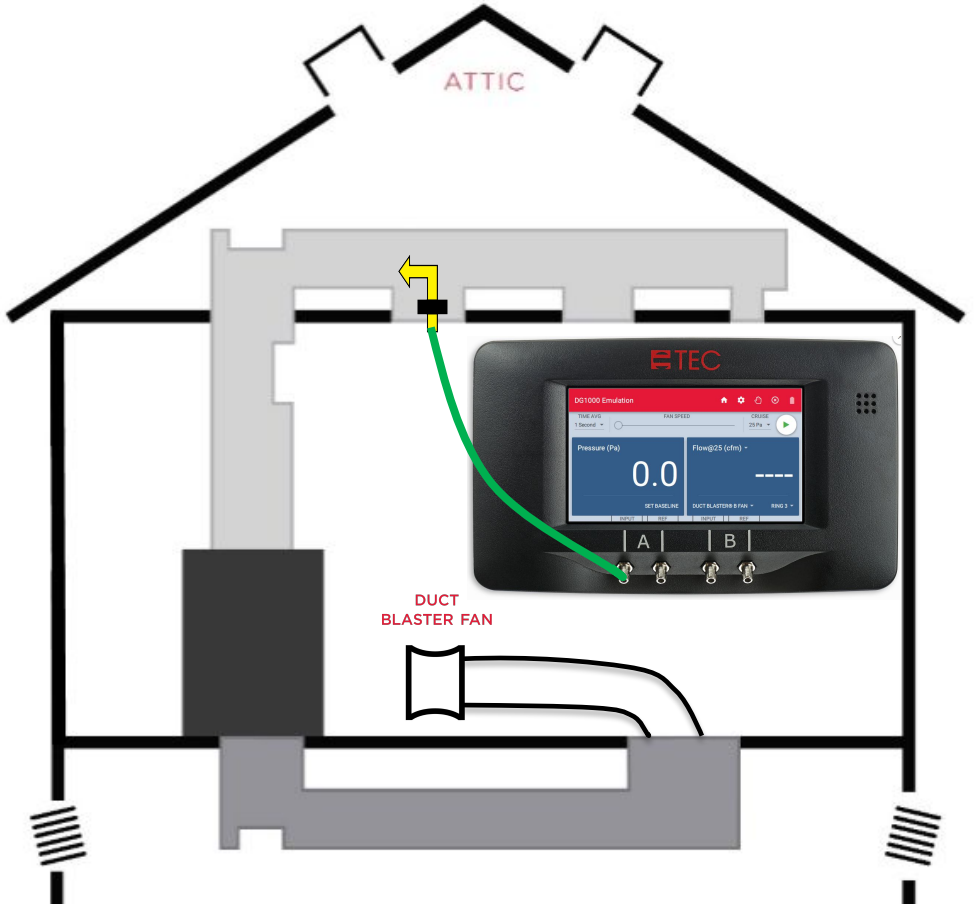


- 3 or fewer returns:
  can connect at largest return



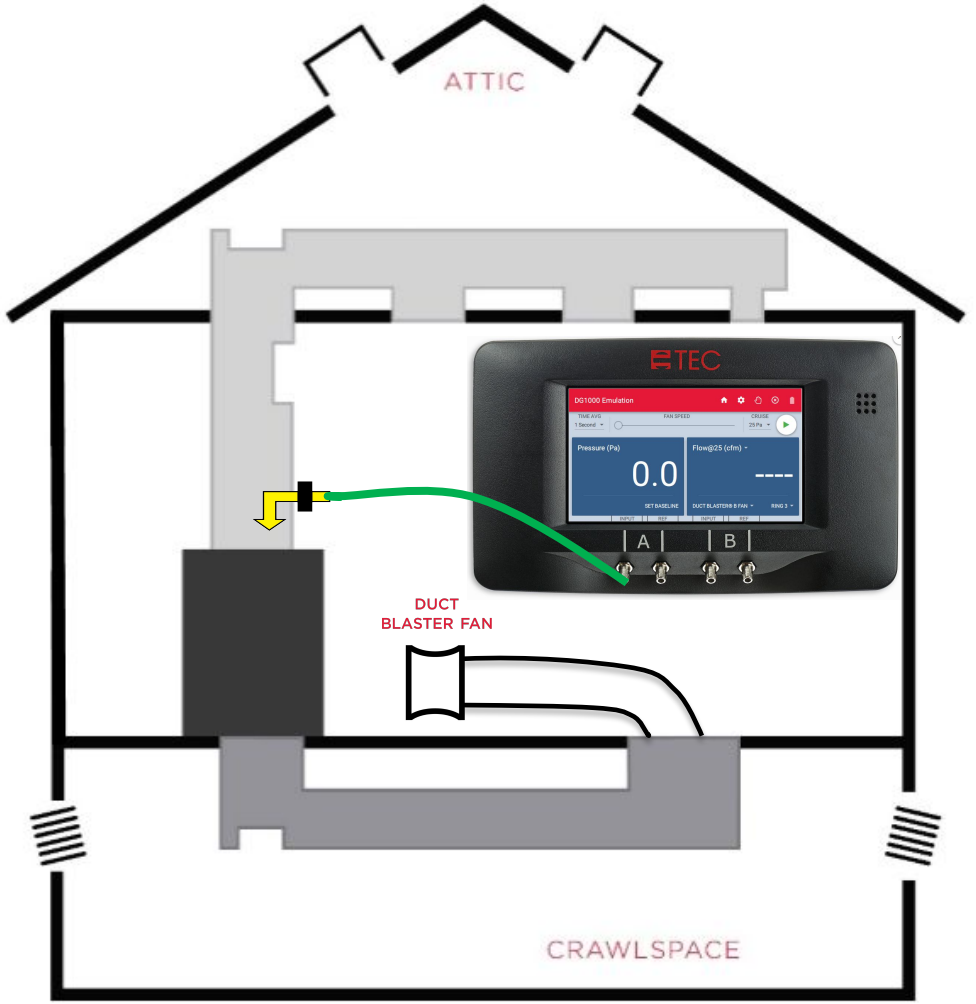
MEASURING STATIC PRESSURE

Option 1: Install static pressure probe in supply register closest to the air handler



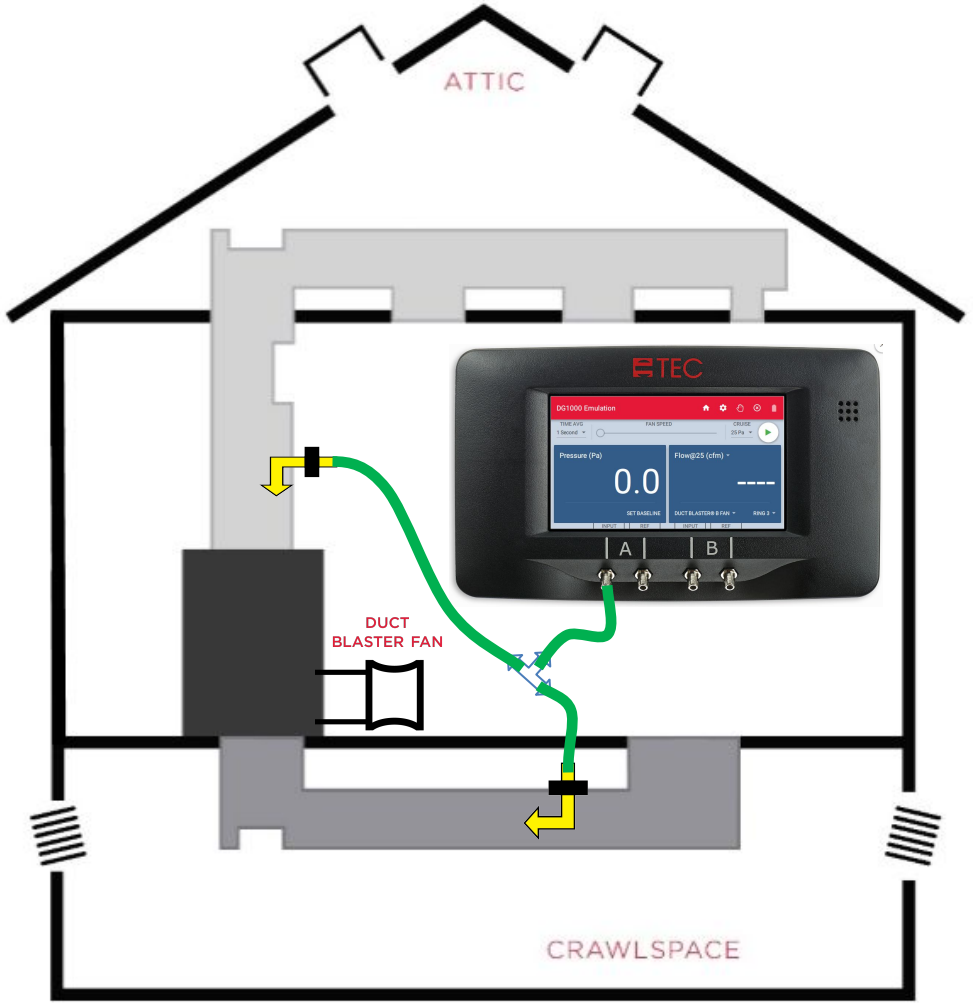
MEASURING STATIC PRESSURE

Option 2: In the supply plenum



MEASURING STATIC PRESSURE

Option 3: If the duct blaster is installed at the air handler, you can use a second probe in the return plenum



TYPES OF TESTS

Both tests can be done by pressurizing or depressurizing the ducts

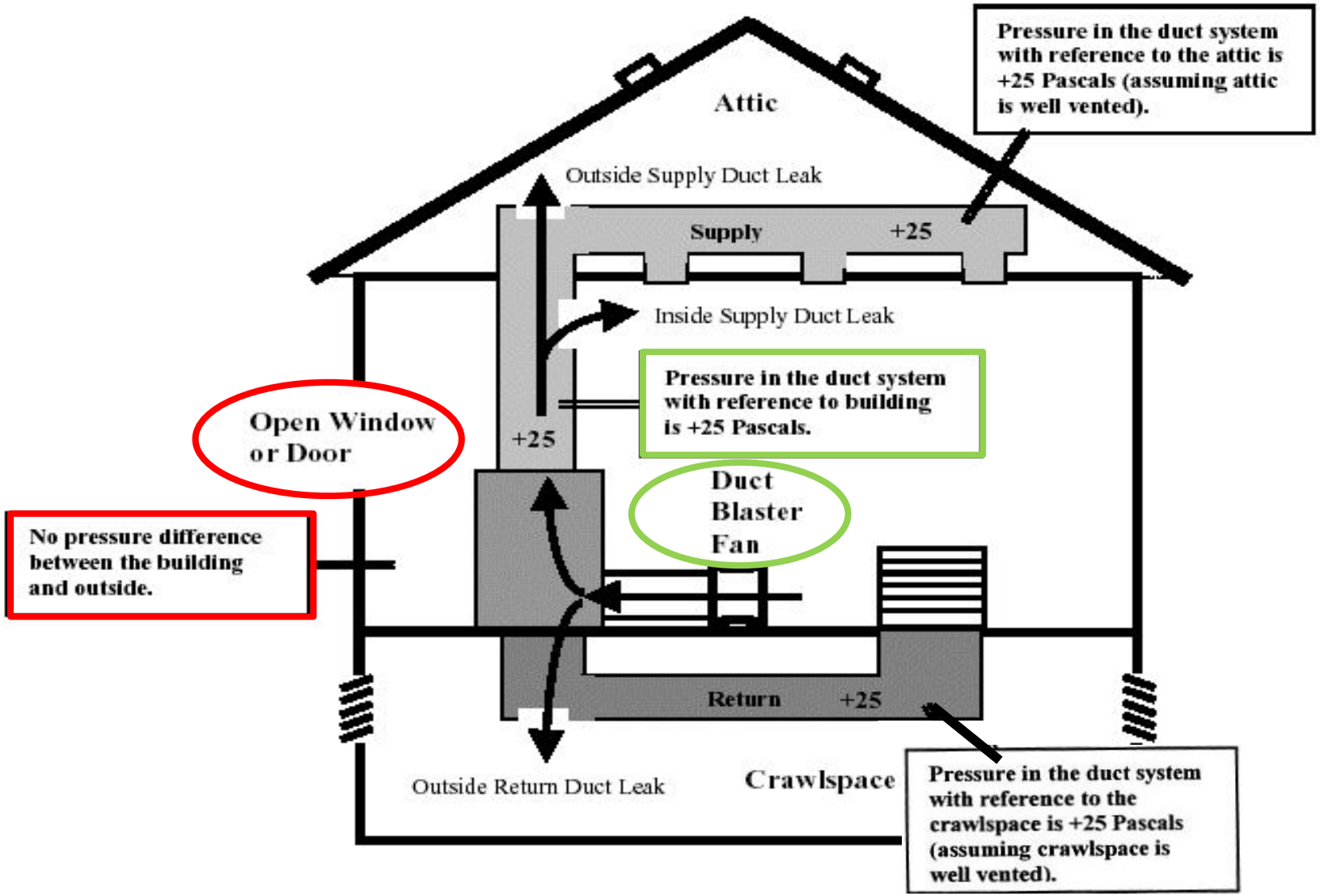
TOTAL DUCT LEAKAGE TEST

How much do the ducts leak?

CONDUCTING A TOTAL DUCT LEAKAGE TEST

- If ducts run through unconditioned spaces, open those spaces to the outside
- Open a door or window between the house and outside
- Bring duct system to 25 Pa +/- 3 Pa
- Use flow@25 Mode or use Can’t Reach Pressure factors
- Document if you are pressurizing or depressurizing
- Return house to as found conditions
- Software or apps will do an automated test and generate a report

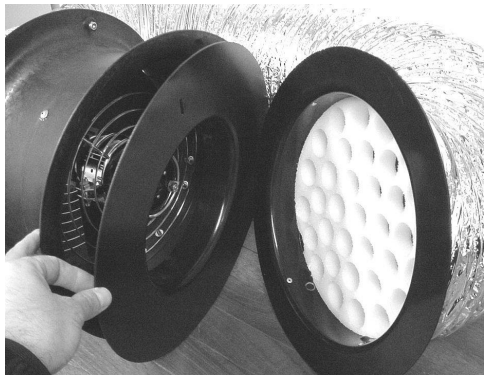
TOTAL DUCT LEAKAGE TEST - PRESSURIZATION



TOTAL DUCT LEAKAGE TEST - DEPRESSURIZATION

What is different?

- Must turn the fan around
- Must include the flex duct
- Have 4’ of straight flex before the fan
- Must install the flow conditioner
- Must use a ring
- Need to connect an additional tube



LEAKY DUCT SYSTEMS (> 500 CFM25)

- Total pressure = Static pressure + Velocity pressure
    - In duct systems total pressure is basically constant, so
    - When velocity goes up, static must go down and vice versa
- Leaky ducts can result in uneven pressure in the duct system
- Do two tests
    - One measuring pressure in closest supply
    - One measuring pressure in farthest supply
    - Average the results

Agenda

- Blower Door Testing
  - Duct leakage with pressure pan
  - Range hood pressure matching method
- Exhaust Fan Flow Meter
- Total Duct Leakage
- Leakage to the Outside
- Zone Pressure Diagnostics
  - Unmodified zone
  - Modified zone

DUCT LEAKAGE TO THE OUTSIDE TEST

How much do the ducts leak to the outside?

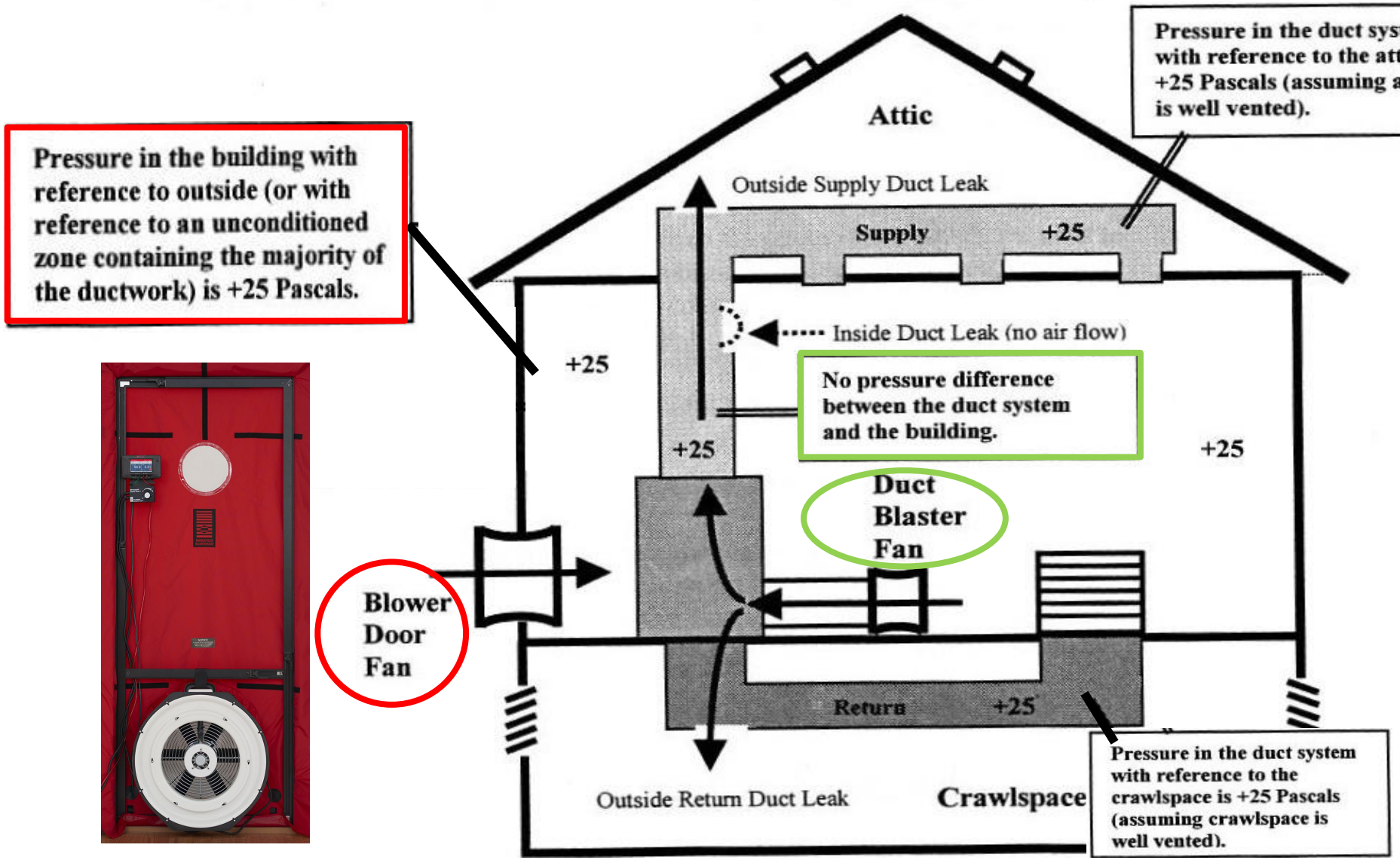
DUCT LEAKAGE TEST TO OUTSIDE TEST

- Setup both the duct blaster and the blower door
- Setup house in blower door test conditions
- If ducts run through unconditioned spaces, open those spaces to the outside
- With blower door and duct blaster sealed, enter a baseline into the gauge.
- Uncap blower door fan and set gauge to cruise 25 Pa.
- Unseal duct blaster and bring duct pressure to 0 Pa (baseline?)

DUCT LEAKAGE TEST TO OUTSIDE TEST

- This test relies on the fact that a leak needs both a pathway and a pressure to exist.
    - If you take away the pathway (sealing) the leak stops, also
    - If you take away the pressure difference across the hole you also stop the leak

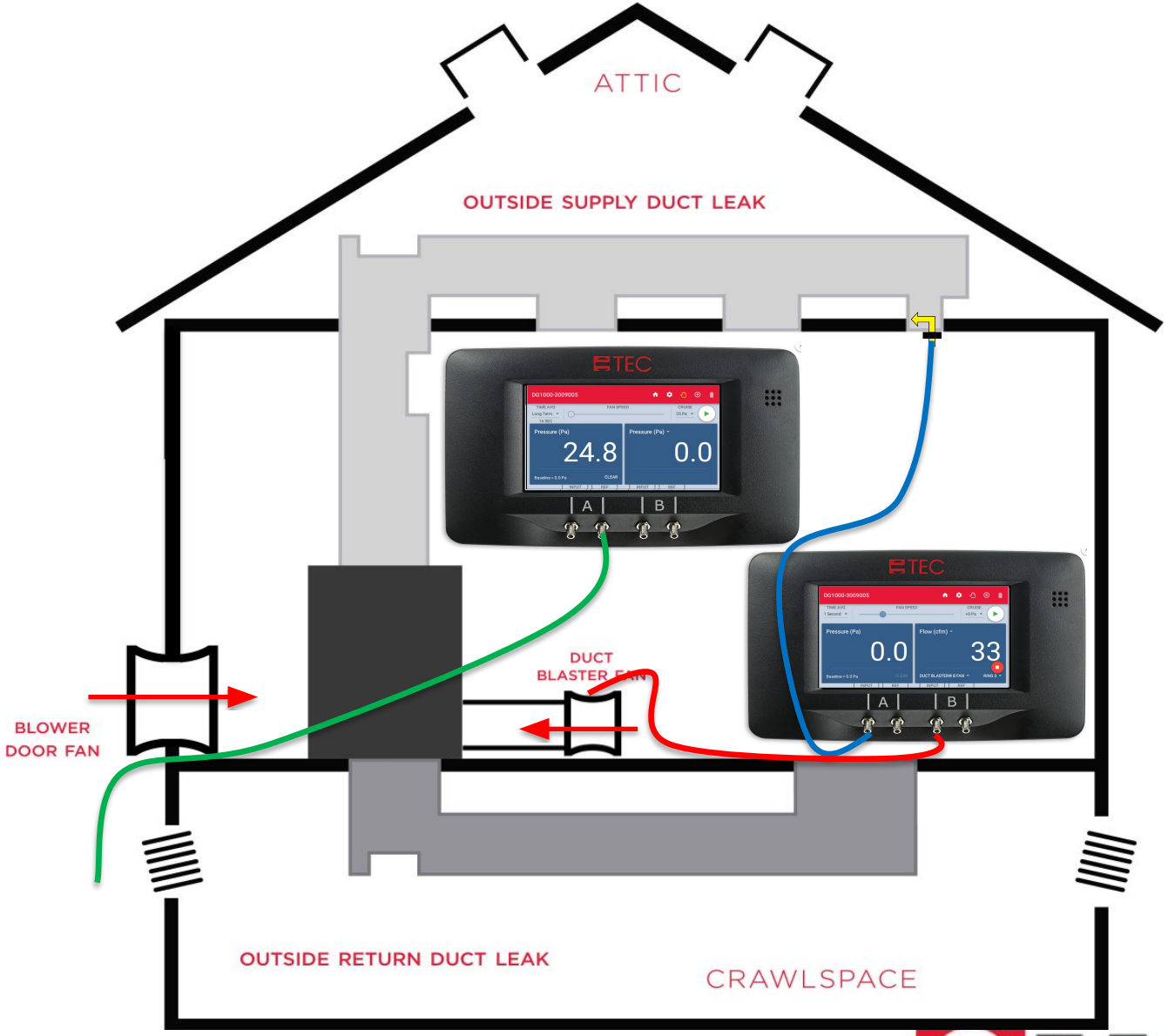
CONDUCTING DUCT LEAKAGE TO OUTSIDE - PRESSURIZATION



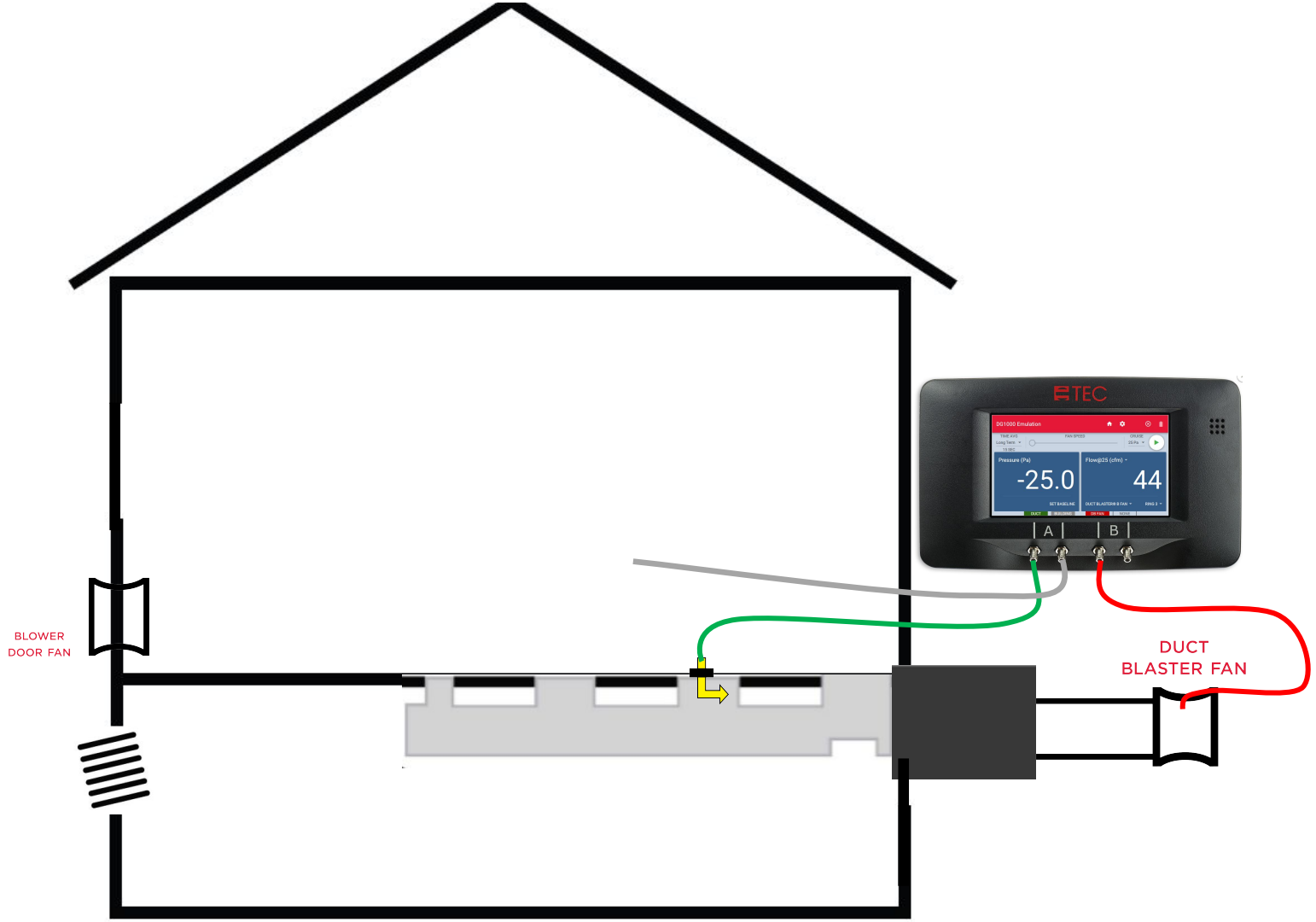
DUCT LEAKAGE TO OUTSIDE - PRESSURIZATION

Double Check:

- Is the house with reference to the outside 25 pa?
- Is the pressure in the duct with reference to the house zero?
- If so, there is no air flow through holes in the ducts that are inside the house.
- The flow you are measuring is only those from leaks outside the house.



DUCT LEAKAGE TO OUTSIDE - PRESSURIZATION



If the gauge is outside of the house. You must measure duct with reference to house

DUCT LEAKAGE TO OUTSIDE

- If unable to reach 0 Pa, drop house pressure and use Can't Reach Pressure Factors

Table 2: Can't Reach Pressure Factors (25 Pa Target)

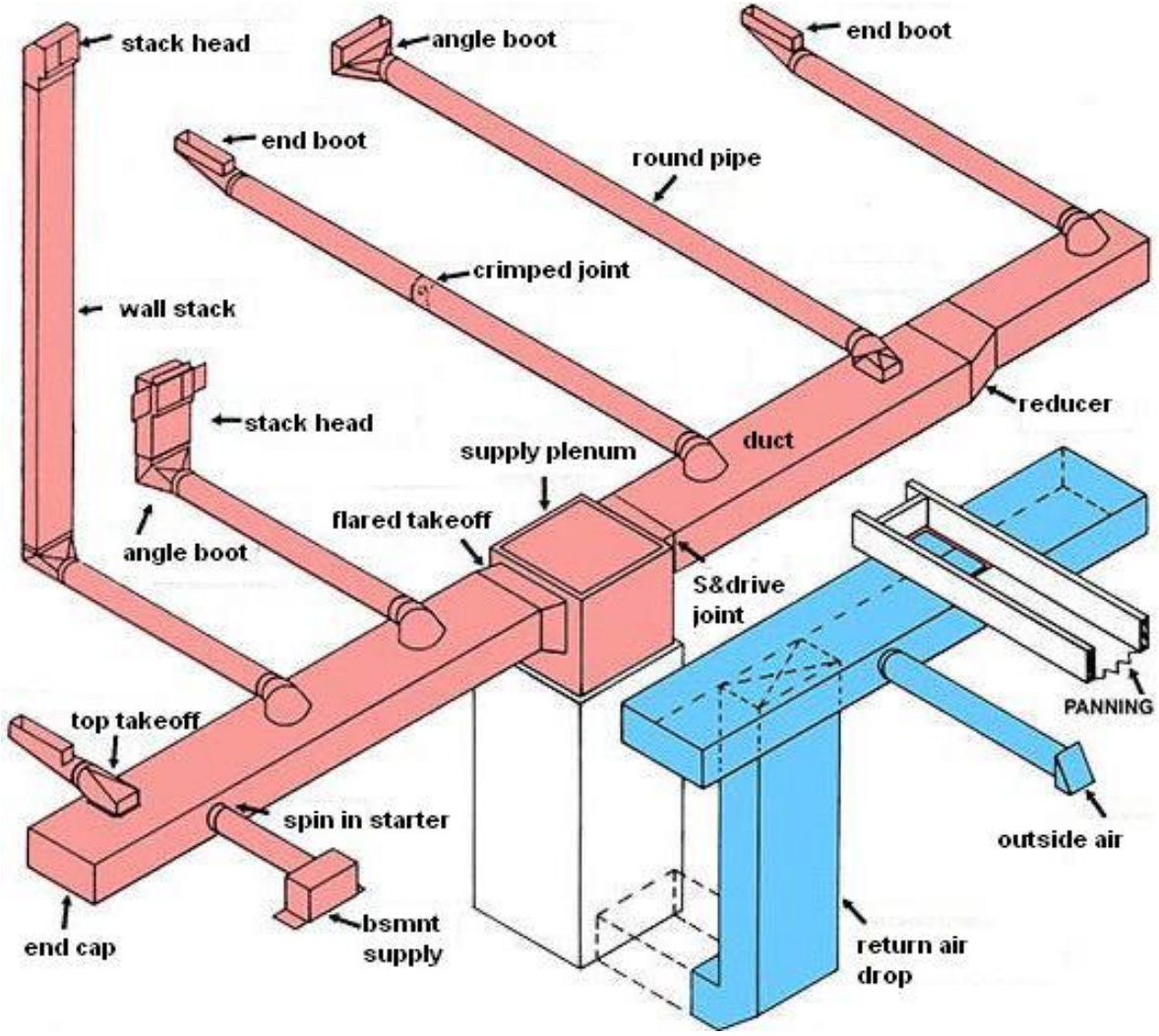
Duct Pressure (Pa)	CRP Factor	Duct Pressure (Pa)	CRP Factor
24	1.02	14	1.42
23	1.05	13	1.48
22	1.08	12	1.55
21	1.11	11	1.64
20	1.14	10	1.73
19	1.18	9	1.85
18	1.22	8	1.98
17	1.26	7	2.15
16	1.31	6	2.35
15	1.36	5	2.63

$$\text{Can't Reach Pressure Factor} = \left\{ \frac{25}{\text{Current Test Pressure (Pa) (Channel A)}} \right\}^{0.60}$$

FINDING DUCT LEAKS

Duct test tells you how much leakage but not where…

DUCT SYSTEM COMPONENTS

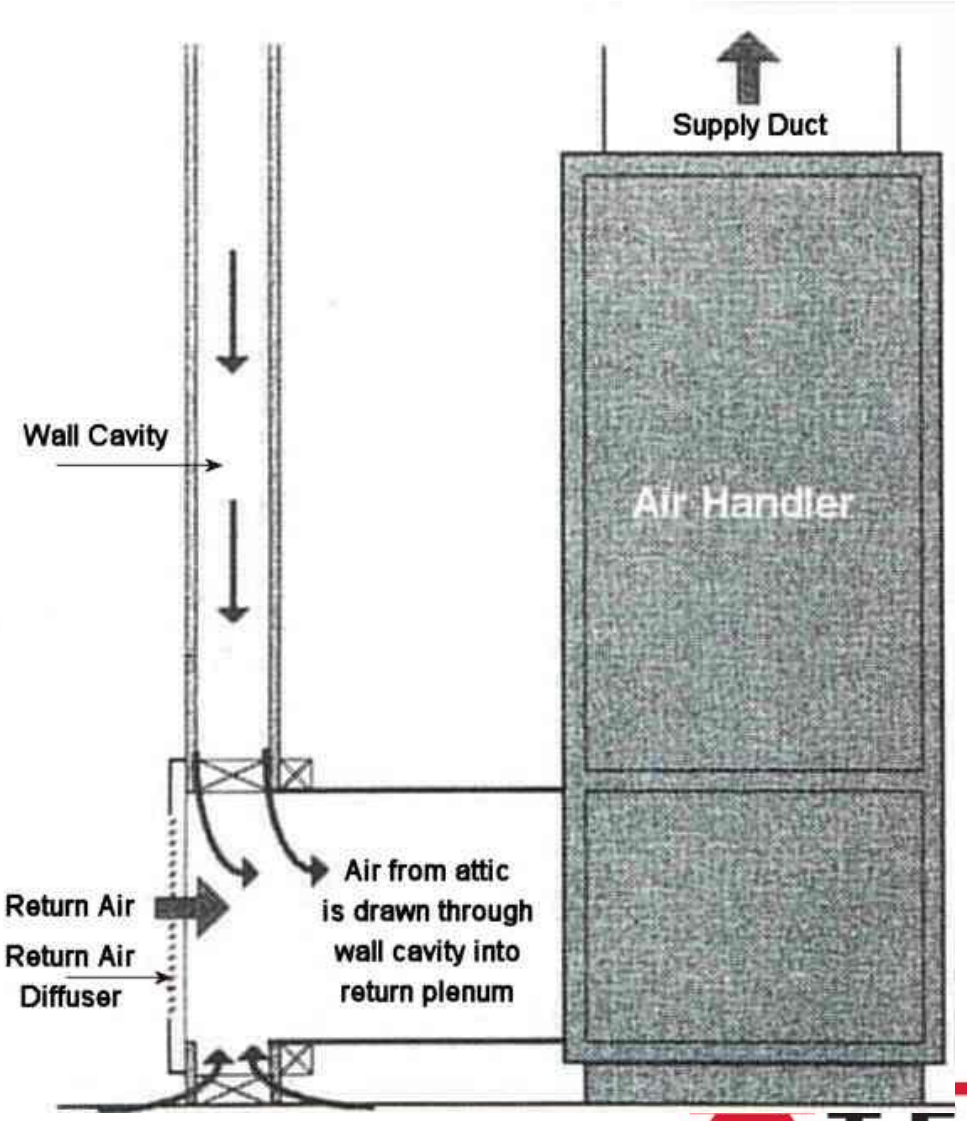


TRUNK TO BRANCH TRANSITIONS

ELBOWS

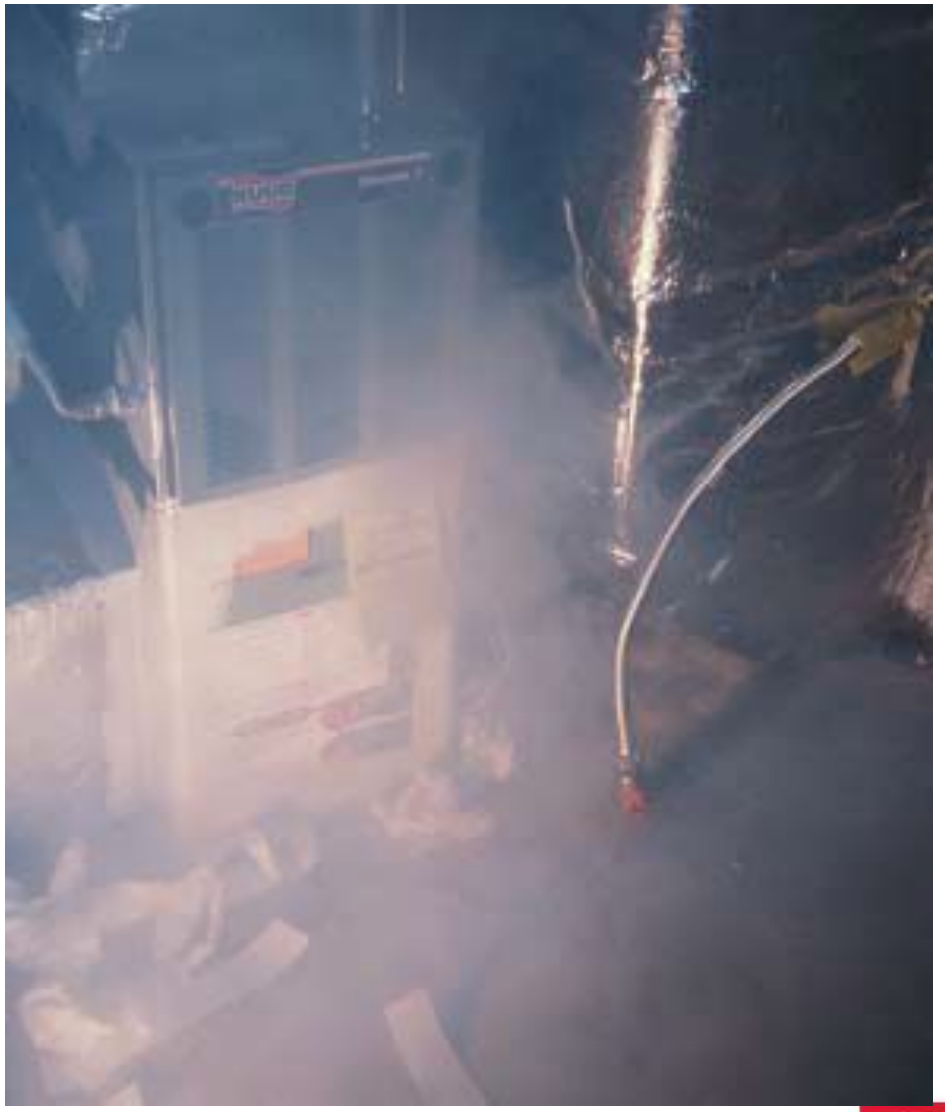
BOOTS

INTERIOR CAVITY LEAKAGE



PANNED RETURNS

FINDING LEAKS: ADDING FOG



Jake McAlpine

612-254-2186

jmcalpine@energyconservatory.com