Pressure Diagnostics with The House of Pressure

New River Center for Energy Research and Training
A Division of Community Housing Partners

Test in and Test Out

- Because when changes are made to a house, we are going to affect what???
  - Health and Safety
  - Durability of the Building
  - Comfort
  - Energy Efficiency

Using Diagnostics to find Interactions

- Pressure and Thermal Boundaries
- Zonal Pressure Testing
- Pressure Pan Diagnostic Testing
- Dominant Duct Leakage
- Worst Case Draft Testing
- Room Pressures

Two Types of Pressure Diagnostics

- With house depressurized by blower door
  - Blower door test
  - Zonal pressure
  - Pressure pan testing
- Using existing air handler and exhaust fans
  - Combustion appliance zone pressure
  - Worst Case Draft Testing

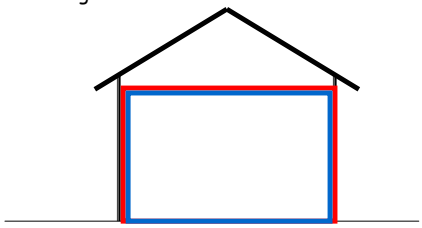
Pressure and Thermal Boundaries

The Pressure Boundary is the air block between Conditioned indoor air and Unconditioned outdoor air

The Thermal Boundary is the insulation between Conditioned indoor air and Unconditioned outdoor air

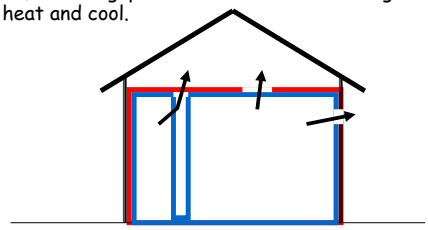
Pressure and Thermal Boundaries

• The Pressure Boundary and Thermal Boundary must be together and continuous.



Pressure and Thermal Boundaries

• If the boundaries are misaligned or If there are holes,voids or gaps this will make the building difficult to heat and cool.



Use your Blower Door more

- The Blower Door can estimate total amount of amount air leakage, but you can also use your Blower Door to find out:
  - Where the air barrier (PRESSURE BOUNDARY) is so we can determine where to air seal
  - If the Pressure Boundary and insulation (THERMAL BOUNDARY) line up
  - Test Duct Leakage with the Pressure Pan

Zonal Testing

This test is is used to determine which areas of the House are INSIDE and which areas are OUTSIDE Pressure (Air) Boundary

Benefits of Zonal Testing

Provides an idea of how well connected two spaces are

Can be a good check for air sealing work

Most of the time, a general indication of tightness is enough for good decision-making

Measuring Zonal Pressures

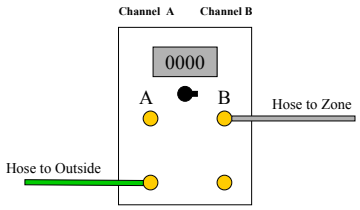
- With the Blower Door at –50 Pascals we can measure the pressure Difference between to Different Zones.
- Zone (is a space that has 2 surfaces)
  - One between House and Zone
  - One Between Zone and Outdoors

Outside Zones and Inside Zones

We want Zones Outside the House (***Unheated Areas***) to be closer to 5O

We want Zones Inside the House (***Heated Areas***) be closer to 0

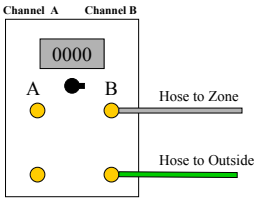
Manometer Setup for Zonal Testing



(This test is done with the house depressurized to -50 PA)

Channel A: is House WRT Outside
Channel B: is Zone WRT House

Verify Reading by Measuring WRT Outdoors



Move Reference Hose from A side to B side

Zone WRT House + Zone WRT Outdoors Should equal the House Pressure (i.e. 50PA)

Zone WRT House Reading is 45PA then

Zone WRT to Outside should be_____PA

Examples of Outside & Inside Zones

Outside Zones
(Unheated)

- ❑Attics
- ❑Garage
- ❑Porches
- ❑Crawlspace
- ❑Basement

Inside Zones
(Heated)

- ❑Interior Walls
- ❑Floors Between Stories
- ❑Crawlspace
- ❑Basement

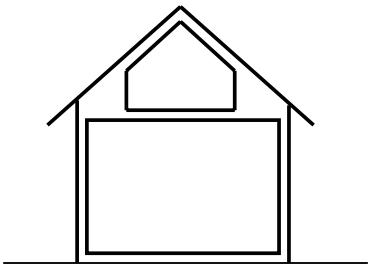
Are the zones where they are supposed to be??

If the zones are NOT where they are supposed to be, we need to seal holes between Inside and Outside. (*wasting money and Energy*)

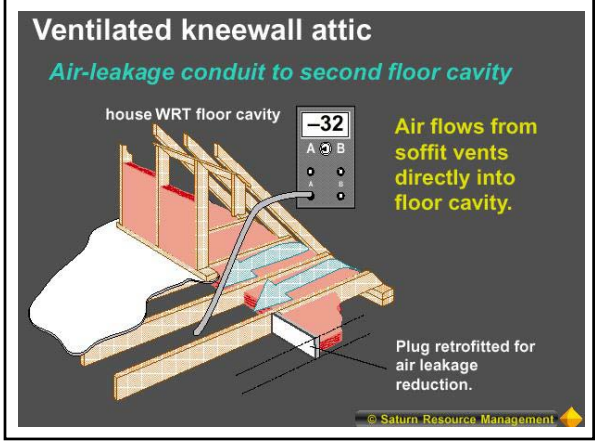
By sealing the holes we stop Air Leakage by making a PRESSURE BOUNDARY

Pressure Boundary (Air Block between Inside and Outside)

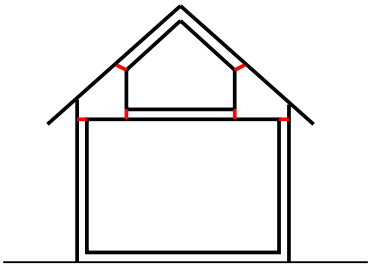
Kneewall Attic



Unsealed/Uninsulated

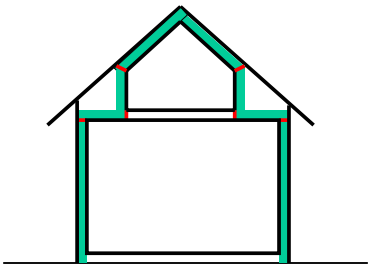


Kneewall Attic



Air Sealed/Uninsulated

Kneewall Attic

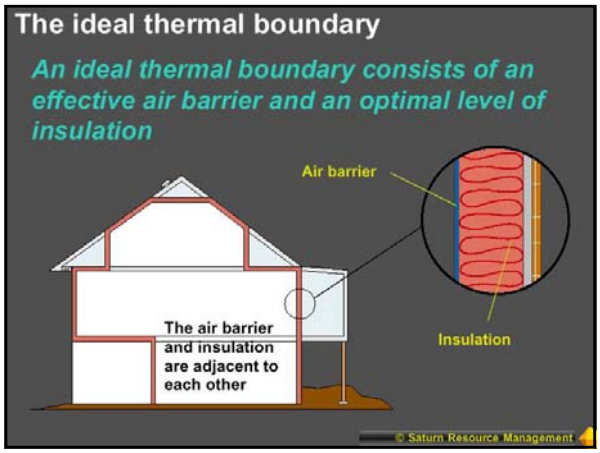


Insulated/Air Sealed

Snow melting because of bypasses in attic kneewall

Interconnection

- Depressurize house to 50 Pa
- Measure pressure to one zone
- Open a door to the other zone, readjust blower door to read 50 again
- If the zones are connected, the pressure in the first zone will change, If not, it won't

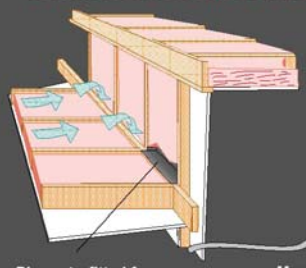


Zonal Pressure Testing

- By dividing the building into zones you can then see if the Pressure Boundaries and the Thermal Boundaries (Insulation) line up

2-level attic in split-level or tri-level homes

Common wall is a possible air-leakage conduit



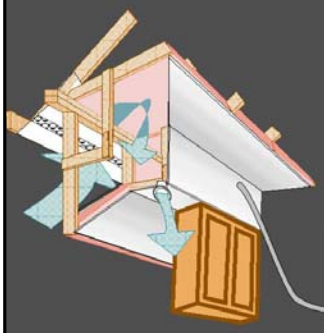
Air leaks between ventilated attic and uninsulated interior wall cavity

Plug retrofitted for air leakage reduction.

Manometer indicates outdoor connection.

Kitchen soffit air leakage

Insulation is a poor air barrier

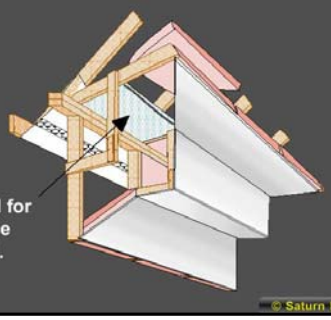


Drywall was installed after soffit framing leaving soffit cavity open to ventilated attic.

Manometer indicates strong outdoor connection

Kitchen soffit air-leakage retrofit

Sealing the top of this cavity reduces air leakage and convection.

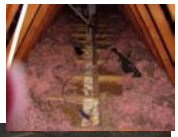


Plug retrofitted for air leakage reduction.

Common By-Passes

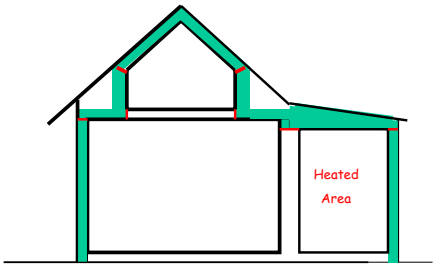



Sealed By-Passes

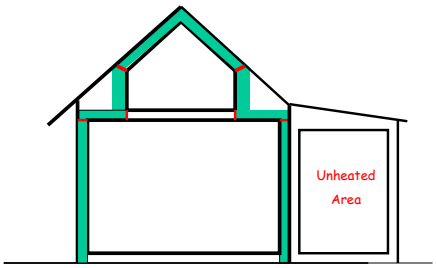
Using Pressure Pan to do Zonal Test

Kneewall Attic



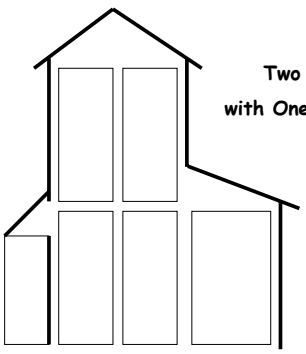
Insulated/Air Sealed

Kneewall Attic



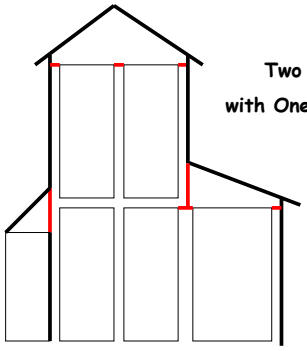
Insulated/Air Sealed

Thermostat and Humidistat on Bypass Wall



Two Story Balloon-Framed
with One Story Add-On and Porch

Unsealed/Uninsulated



Two Story Balloon-Framed
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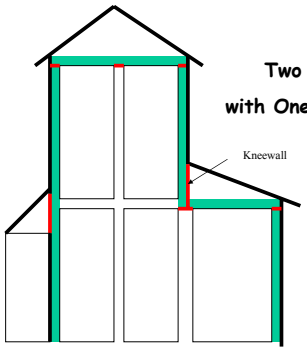
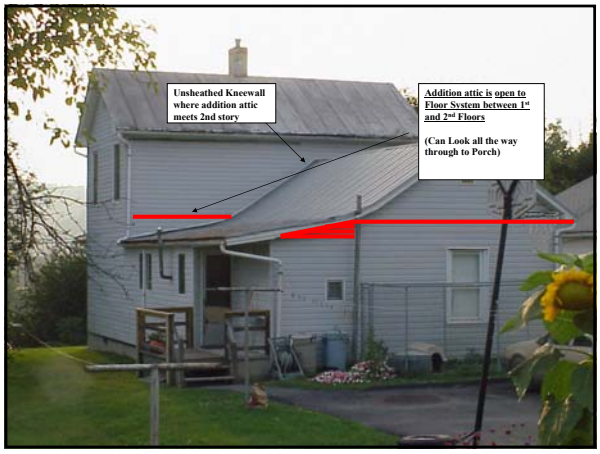
Air Sealed/Uninsulated



Two Story Balloon-Framed
with One Story Add-On and Porch

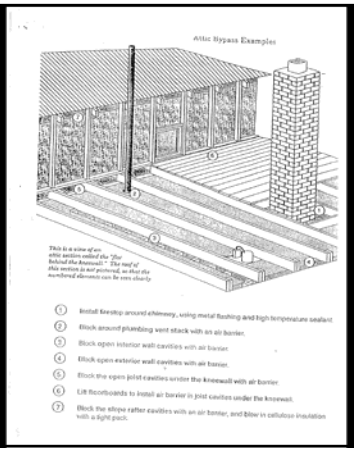
Insulated/Air Sealed

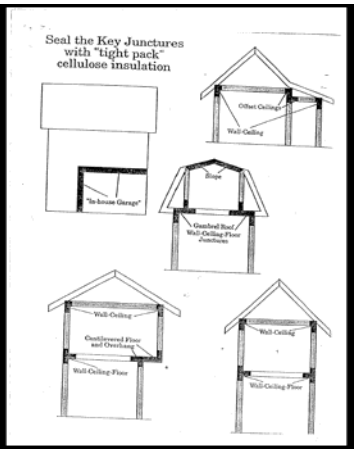


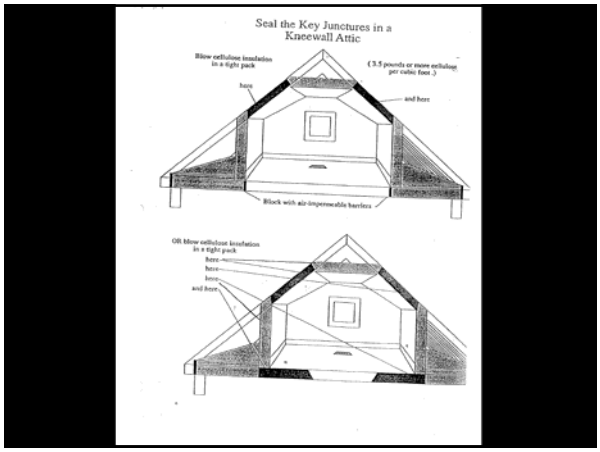
Porch is Open to **Upstairs** and **Downstairs** Exterior Walls

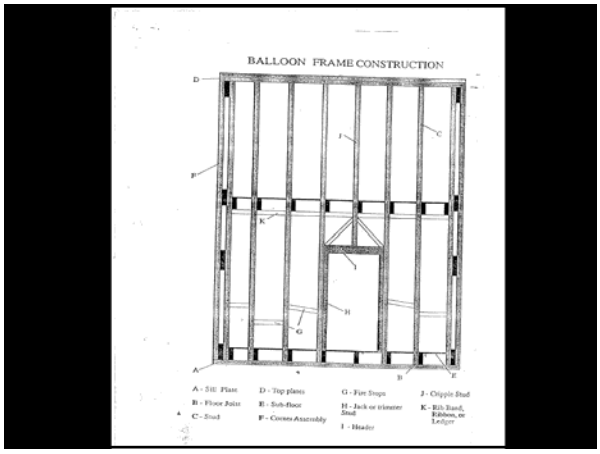
Porch is open to Floor System between 1st and 2nd Floors

(Can Look all the way through to Attic above single story)









Test Key Areas

- Attics, Side attics, Porch roofs
- Garages,Basements, Crawlspaces
- Chases (plumb, elec, duct, chimney)
- Plumbing Access, Duct Location, Soffits

Keep It Simple

- Record basic pressure measurements
- Explain bad pressure readings (ex 10 attic)
- Should take very little time (Bdoor is all ready up)

Take Pressures to make useful Decisions

- Decide what's Inside and what's Outside
- Determine Pressure & Thermal Boundaries

- Where should pressure & Thermal Boundaries be?
- Duct Location (In or Out) & where should be?
- Do the Pressure and Thermal Boundaries line up?

Where Should We Start?

- Look at House, tests, talk to client, fuel bills to understand house & how it should work

- Do the work and remeasure when think done
- Outside (Attic, Garage) Should be more outside (Closer 50)

- Inside (Interior wall, Chase) Should be more inside (Closer 0)

- Check zones with no change in right direction

Just a Tool

- Doesn't Replace Common Sense (Head,Eyes)

- Testing will help a lot in understanding complicated houses along with other observations

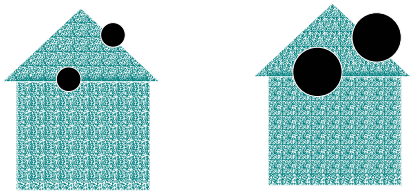
- If get a reading of 46 to 50 PA check Attic WRT to outside (should add to 50) May have a lot of venting (Make sure look)

- If unusual readings (Check hose for pinch, disconnect,plugged)

Pressures and Leakage

Attic Zonal Reading of 25pa

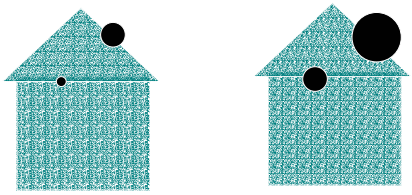
Means hole between Attic and House is
Same size as Hole Between Attic and Outdoors



Pressures and Leakage

Attic Zonal Reading of 48pa

Means hole between Attic and House is
1/8th size of Hole Between Attic and Outdoors



Pressures and Leakage

Zone Pressures

Zone-House	Zone-Out
12	38
25	25
37	13
41	9
45	5
48	2
49	1

Relative Size of Leaks

Zone-House	Zone-Out
2	1
1	1
½	1
1/3	1
¼	1
1/8	1
1/13	1

Zone and ZPD Definitions

- Direct Measurement ZPD (Pressure Only) lets us know whether the zone is more indoors or more outdoors
- Advanced ZPD can be performed on any zone with an opening to estimate the size of the leakage in Square inches, Air Flow through each barrier, and available CFM50 reduction

Advanced Zonal Pressure Diagnostics

- Existing Methods of Quantifying Air leakage
  - Add a hole
  - Flow Method (Open a door)
  - Estimate venting

Add a Hole, Low-Tech Version

- With house at 50, measure house-zone
- Open a hole (attic hatch) just big enough to cut the house-zone pressure in half
  - Keep house at 50
- The hole you added is roughly equal to the existing leakage

New Zone Pressure Diagnostics

- Study Completed by Center for Energy and Environment, Michael Blasnik & Assoc. and the Energy Conservatory
- To test out how accurate the current tests are and when to use them
- Actually ended up creating a Hybrid method by combining Add a hole and Flow Method. To crosscheck and increase repeatability

When to Do Advanced Zonal Pressure Diagnostic Testing

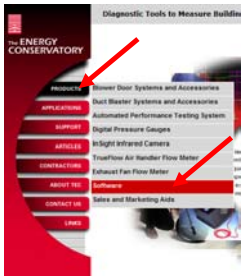
- Important to access amount of leakage for
  - IAQ issues (How much Leakage between Garage, or Moldy crawlspace and house)
  - Durability Issues (How much leakage of moist house air leaking into attic of cold climate house)

New Zone Diagnostics

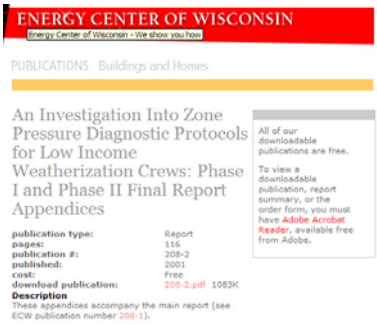
- Previously had programmed new hybrid method into a spreadsheet, and has now develop into a stand alone windows program, and currently developing for palm by The Energy Conservatory
- Rick Karg is working on adding this to the TI-86 Calculator

ZPD Utility for PC

- Available at www.energyconservatory.com
- Select Products link then click on Software
- Scroll to bottom of page to download installation file



- ZPD Study Available at Energy Center of Wisconsin website www.ecw.org

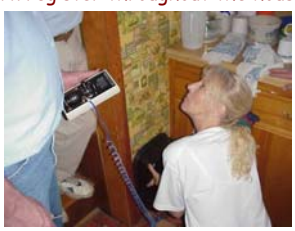


- To get directly to download page visit

http://www.ecw.org/ecw/productdetail.jsp?productId=384

Pressure Pan Test

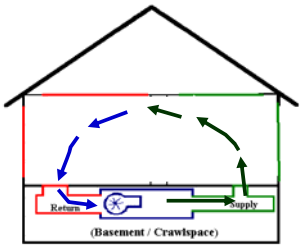
This test is done with the Blower Door depressurizing the house and is used to give a general idea of where leak sites are in ductwork by measuring the pressure at each supply and return register throughout the house.



What is Ductwork?

Ductwork circulates heated or cooled air inside the home.

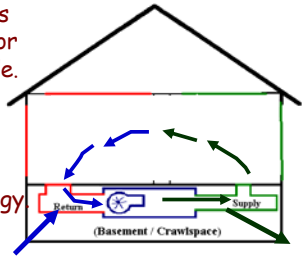
Ductwork should be sealed so that there are no leaks.



Why Do Pressure Pan Testing?

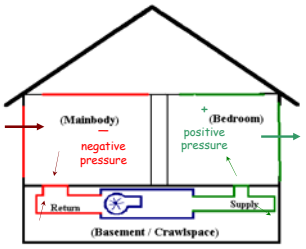
If there are Duct Leaks your are losing heated or cooled air to the outside.

This makes the house uncomfortable, and wastes Money and Energy



All Holes are Not Created Equal

Duct leakage can also create positive and negative pressures on the building by delivering and taking air from the wrong places.

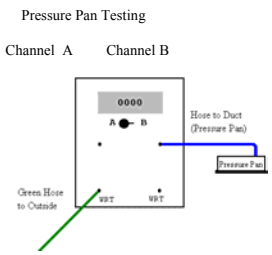


Finding Duct Leaks with the Pressure Pan

With the Blower Depressurizing the House to –50, we can test for duct leakage by Placing a Pan with a pressure tap over each supply and return register to measure the pressure in the duct.

The idea is to Quickly check each register to get an idea of where the major leaks are.

Manometer Setup for Pressure Pan Testing



Channel A: is House WRT Outside
Channel B: is Duct WRT House

Duct Leakage with the Pressure Pan

- Since ductwork circulates inside air we should get a pressure reading near 0. The Higher the reading, the leakier the Duct in that vicinity.
- If we get a reading higher than 1 we want to seal the Duct with Mastic (not duct tape).

Quality Control

- This test can be performed after Duct Sealing is done as measure of Quality Control.
- Lets crew know how well the duct was sealed and if anything was missed.

Pressure Pan Results

Pressure Pan Test				(Duct WRT House)							
	Location	Before	After		Location	Before	After		Location	Before	After
1	Living Room	4.2	0.5	8	RETURN	15.9	0.8	15			
2	Dining Room	6.2	0.4	9				16			
3	Kitchen	8.3	0.5	10				17			
4	Bathroom	6.0	0.8	11				18			
5	Bedroom 1	4.2	0.5	12				19			
6	Bedroom 2	4.7	0.4	13				20			
7	Bedroom 3	3.2	0.2	14				21			

Intentional Depressurization

- Blowers Doors intentionally Depressurize a home to measure air leakage at -50 Pascals.
- When we do a Blower Door test we turn off all the heating and cooling equipment, *(including gas water heaters),* so we do not cause **Backdrafting**.

Backdrafting

Spillage of flue gases from combustion equipment into the home.

These gases can be harmful and even Deadly, especially Carbon Monoxide which is odorless, colorless, and tasteless.

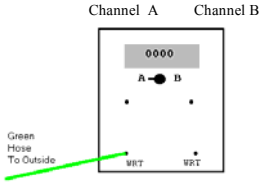
Backdrafting is caused by Depressurization (Negative Pressure)

Unintentional Depressurization

- Depressurization (Negative Pressure) can also be caused by duct leakage, exhaust fans, and even door closure.
- We want to be able to use or Heating and Cooling equipment without causing Backdrafting.
- We also want to avoid positive pressures.

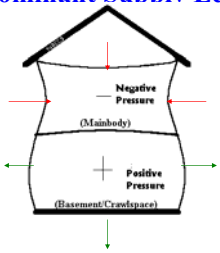
Dominant Duct Leakage Setup With Manometer

Channel A: is House WRT Outside



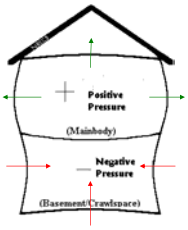
(Turn Air Handler on and off several times)
(Notice the immediate pressure change on channel A)

Effects of Duct Leakage
(Dominant Supply Leak)



	Mainbody	Zone with Leak
Dominant Supply Leak	- (Negative)	+ (Positive)

Effects of Duct Leakage
(Dominant Return Leak)



	Mainbody	Zone with Leak
Dominant Return Leak	+ (Positive)	- (Negative)

Dominant Duct Leak Readings

0 Zero	NO Leaks / Equal Leaks / House to Leaky
- Negative Pressure	Dominant Supply Leak
+ Postive Pressure	Dominant Return Leak

- **Negative Pressure:** Can cause Backdrafting and Flame Roll out
  Pulls in unconditioned air, Pollutants and Soil Gases
- **Positive Pressure:** Pushes out
  (Pollutants, Flue Gases, Conditioned Air and Moisture)
- **(-Negative Pressure) Can cause backdrafting (-12.5) Can cause Flame Roll out**

Combustion Appliance Zone (CAZ) Testing

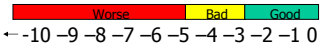
- This test is done to determine if there is a possibility of a Combustion Appliance backdrafting because of…..
- Duct Leakage
- Door Closure
- Exhaust Fans or Equipment

"Worst-Case" Scenario

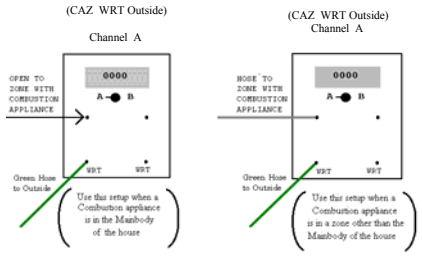
- We use the existing fans (air handler, exhaust fans, clothes dryer, etc) to create the largest possible negative pressure in the area of the appliance. Then we check…..
- How strong is that negative pressure in the Combustion appliance zone?
- Will the appliance draft under that condition?
- If so, how strong is the chimney draft?

What is a Safe Reading

- The greater the Depressurization the more negative our pressure reading will be and the greater the chance of Backdrafting



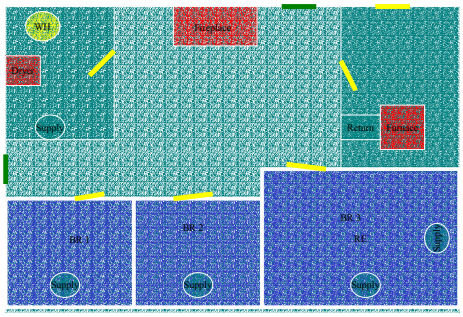
COMBUSTION APPLIANCE ZONE TESTING



House Depressurization Limits

(Can Cause Backdrafting)

Appliance	Chimney Height (ft) Appliance	Unlined Chimneys on Exterior Wall	Metal Lined, Insulated or Interior Chimneys
Gas-Fired Furnace, Boiler, DHW Heater	13 or Less 14-20 21+	-5pa -5pa -5pa	-5pa -6pa -7pa
OIL-Fired Furnace, Boiler, DHW Heater	**13 or Less** **14-20** **21+**	**-4pa** **-4pa** **-4pa**	**-4pa** **-5pa** **-6pa**
FIREPLACE	N/A	-3pa	-4pa
Low-Excess Air Fireplace, Wood stove	**N/A**	**-10pa**	**-10pa**
Induced Draft Appliance	N/A	-15pa	-15pa
From: CMHC Chimney Safety Users' Manual (Reference #4 Appendix A)			
Note: Under summertime conditions, actual HDL's may be lower than shown above			



Combustion Appliance Zone TEST Steps		List each CAZ location and appliances in each					
		Location 1		Location 2		Location 3	
		Pre	Post	Pre	Post	Pre	Post
1	Setup Manometer and Pressure hoses to measure CAZ (WRT) Outdoors						
2	All interior doors open, Measure Baseline Pressure	PA	PA	PA	PA	PA	PA
3	Turn on all Exhaust Fans *except whole house fans						
4	Close all interior doors *except doors to rooms with exhaust fans*						
5	Is Blower Door being used to simulate fireplace at 300 cfm? (see Ring B)	Y N	Y N	Y N	Y N	Y N	Y N
6	If Door from CAZ to House Open it (Record CAZ pressure WRT outside)	PA	PA	PA	PA	PA	PA
7	Close Door from CAZ to House (Record CAZ pressure WRT outside)	PA	PA	PA	PA	PA	PA
8	Turn on Furnace Blower (Record CAZ pressure WRT outside) *check position of interior doors for worst case with smoke puffer*	PA	PA	PA	PA	PA	PA
9	If Door from CAZ to House Open it (Record CAZ pressure WRT outside)	PA	PA	PA	PA	PA	PA
10	Recreate Worst Case Conditions for each CAZ. *(Complete this and following steps on each Heating Inspection form)*						
11	Perform Worst Case Draft and Combustion Tests for each appliance under this worst case condition						
*There should be no spillage after 30 seconds and Draft should be established after 5 minutes *Monitor ambient CO in CAZ while doing these tests if CAZ –5pa or worse, if ambient CO gets above 20ppm discontinue testing							

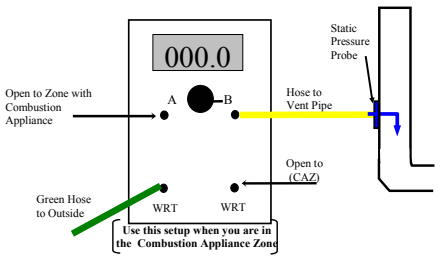
Minimum Acceptable Draft in Pascals

(for natural draft appliances)

Temperature	Gas Fired	Oil Fired
80 >	-1.0	-7.0
61 – 80	-2.0	-9.0
41 – 60	-3.0	-11.0
21 – 40	-4.0	-13.0
< 21	-5.0	-15.0

WORST-CASE DRAFT TESTING

Channel A (CAZ WRT Outside) CAZ Depressurization
Channel B (Vent Pipe WRT CAZ) Worst Case Draft



No Return Duct work

CAZ -10pa

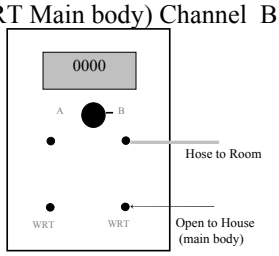
Flue Gases were coming into house because of Depressurization created by the Air Handler

Room Pressure Testing

- This test is used to measure room pressures created by the air handler and to determine if there are any problems associated with the pressures.

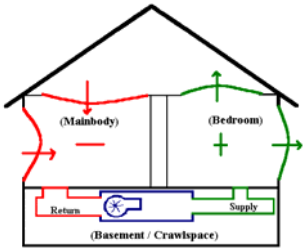
Room Pressure Testing

(Room WRT Main body) Channel B



(Use Door Gauge if need to do Pressure Relief)

Effects of Interior Door Closure



Need to Get Return From Behind Closed Doors (to Equalize Pressures)

Pressure Relief Needed

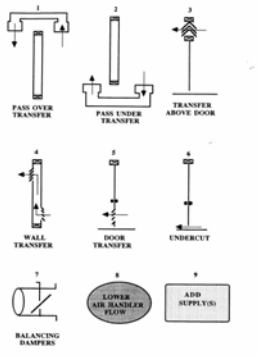
- Rooms are Pressurized
- Main body is Depressurized to an unsafe condition

Pressure Relief Solution

- Pressure Relief has equalized pressure in rooms
- Main body is now in a safe condition
- Fixed Health & Safety, Comfort, Durability problems and increased Energy Efficiency by doing Pressure Relief

How Much Sq" Relief is needed

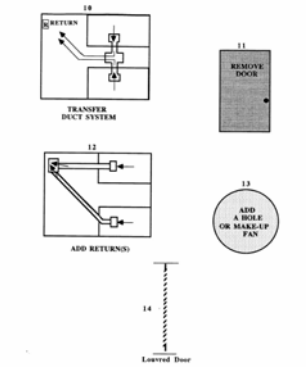
- Open door wide enough to relieve Pressure
- Use Door Gauge or Tape to measure width of door opening
- Look up door size on chart & multiply by measured door opening to get sq" needed for Pressure Relief



Source:

John Tooley

(Pressure Balancing a House)



Source:

John Tooley

(Pressure Balancing a House)

Door Opening at TOP and SIDE only

DOOR Height	WIDTH 18"	24"	28"	30"	32"	34"	36"	38"	TOP-SIDE 40"
2'0"	28.5	30.0	31.0	31.5	32.0	32.5	33.0	33.5	34.0
3'0"	40.5	42.0	43.0	43.5	44.0	44.5	45.0	45.5	46.0
4'0"	52.5	54.0	55.0	55.5	56.0	56.6	57.0	57.5	58.0
5'0"	64.5	66.0	67.0	67.5	68.0	68.5	69.0	69.5	70.0
6"0"	76.5	78.0	79.0	79.5	80.0	80.5	81.0	81.5	82.0
6'4"	80.5	82.0	83.0	83.5	84.0	84.5	85.0	85.5	86.0
6'8"	84.5	86.0	87.0	87.5	88.0	88.5	89.0	89.5	90.0
6'10"	86.5	88.0	89.0	89.5	90.0	90.5	91.0	91.5	92.0
7'0"	88.5	90.0	91.0	91.5	92.0	92.5	93.0	93.5	94.0
8"0"	100.5	102.0	103.0	103.5	104.0	104.5	105.0	105.5	106.0

Source: John Tooley (Pressure Balancing a House)

Opening with TOP, SIDE and Bottom

DOOR Height	WIDTH 18"	24"	28"	30"	32"	34"	TOP-SIDE-BOTTOM 36"	38"	40"
2'0"	33.0	36.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0
3'0"	45.0	48.0	50.0	51.0	52.0	53.0	54.0	55.0	56.0
4'0"	57.0	60.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0
5'0"	69.0	72.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0
6'0"	81.0	84.0	86.0	87.0	89.0	90.0	91.0	92.0	93.0
6'4"	85.0	88.0	90.0	91.0	92.0	93.0	94.0	95.0	96.0
6"8"	89.0	92.0	94.0	95.0	96.0	97.0	98.0	99.0	100.0
6'10"	91.0	94.0	96.0	97.0	98.0	99.0	100.0	101.0	102.0
7'0"	93.0	96.0	98.0	99.0	100.0	101.0	102.0	103.0	104.0
8'0"	105.0	108.0	110.0	111.0	112.0	113.0	114.0	115.0	116.0

Source: John Tooley (Pressure Balancing a House)

Recording Room Pressure Readings

Pressure in Individual Rooms (Room WRT Main body)

	Room	PR	Ref	Inter	Aft		Room	PR	Ref	Inter	Aft		Room	PR	Ref	Inter	Aft
1	Bedroom	88	2	6	1	5						9					
2						6						10					
3						7						11					
4						8						12					

Pressure Diagnostics

- Can help us to figure out what leaks and where
- Are the leaks worth sealing?
- Can show where the pressure boundaries are
- Can help analyze savings opportunities
- Can help crews and inspectors evaluate work
- Can tell us if spaces are being (de)pressurized
- Can help avoid backdrafting

Test in and Test Out

- Because when changes are made to a house, we are going to affect what???
  - Health and Safety
  - Durability of the Building
  - Comfort
  - Energy Efficiency