October 7, 2016

RESIDENTIAL MECHANICAL SYSTEMS PERFORMANCE TESTING & TRAINING

Fort Collins HVAC Training Series

Today

- Training
- Tools and Resources
- **MS Performance Testing Submittal**
  - Work completing the form together
  - Demonstrate tools and tests
  - Complete Section-by-section
  - Use your sniffer
  - Common challenges
  - Questions

Two-way. Participate! Ask questions!

Be prepared to answer questions!

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Goals for Today

- Complete steps toward becoming proficient at Residential Mechanical Systems Performance testing and reporting
- Learn the What, Why and How
- Create an additional service opportunity to clients

Big picture: Increase quality + consistency for better building performance

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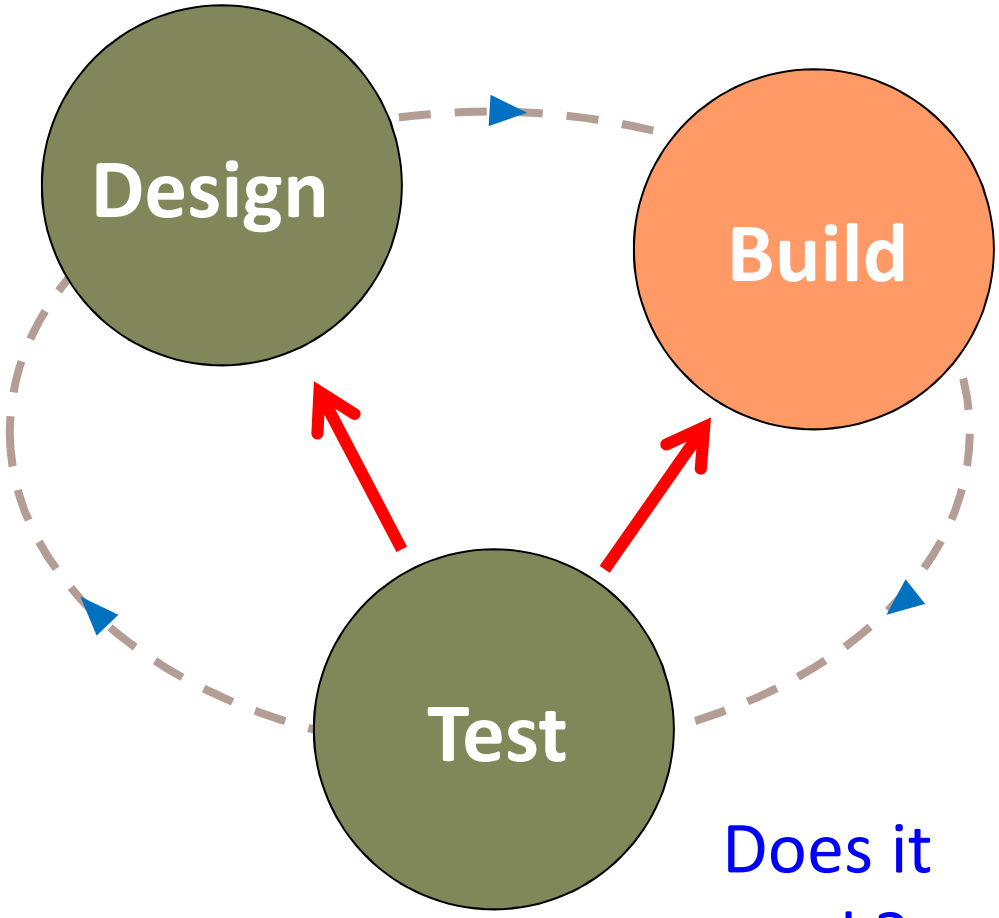
Three Critical Steps

Quality systems start here



Is it there?

Does it work?

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2012 IRC/IMC + Fort Collins Amendment

IRC M1309 – Testing and Verification

M1309 Testing and verification

- Installed heating, cooling and ventilation systems shall be performance-tested by an approved agency
- And adjusted to operate within design specifications, in accordance with ANSI/ACCA QI 5-2007 HVAC Quality Installation Specification
- Documentation of results shall be submitted to the Building Official prior to approval

(All residential compliance paths)

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HVAC PROFICIENCY PROCESS

Resources

Available at www.fcgov.com/building/greenclasses.php

Adopted for 2012 I-Codes- March 1, 2014

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City of Fort Collins Residential Mechanical Systems Design Submittal Updated 3/1/2014

For code references and training reminders/tips, see most current version of "Residential New Construction Mechanical Systems Design Submittal Guide."

Project Information

Builder: _____ Builder model: _____

☐ Site-specific submittal Address: _____ Direction front of house faces: _____

☐ Stock plan submittal City of Fort Collins stock plan #: _____

If the plan set shows options, what options affecting the thermal envelope are accounted for in this mechanical design?

☐ Full basement ☐ Full crawl space ☐ Basement + crawl ☐ Walkout basement Other foundation: _____

☐ Bonus room ☐ Other significant floor area change: _____

☐ Window area changes > 20 sf: _____

☐ Other significant options: _____

Other notes regarding house configuration: _____

Source of information for energy specs (R-values, windows, etc.): _____

Designer

Designer's name: _____ Company: _____

Signature: _____ Date: _____

Local Exhaust -- Bath Fans

Exhaust Pickup Location (1)	Code-required?	Operation (2) + Minimum Airflow Requirement (CFM 5000')	Control and Other Notes (Does any fan also provide whole-house ventilation?) (Specify location of any remote fans)
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	
	__ Y __ N	__ I (50 cfm) __ C (20 cfm)	

(1) Match room names on plans (2) I = Intermittent C = Continuous

Where do I get Design values from?

COMPLETING THE PERFORMANCE TESTING FORM

Performance Testing Form

City of Fort Collins Residential Mechanical Systems Performance Report

Updated 3/1/2014

This form is a record of testing targets and results, with Pass/Fail outcomes. For information on measurement tools and testing techniques, see the "Residential New Construction Mechanical Systems Testing Guide." The guide and this form may be periodically updated; check the Building Services web site for the current version.

This form must be completed and signed by an "Approved Agency," and submitted to Building Services as a requirement for receiving a C.O.

Color key	Target or limit	Measured value to compare with target or limit	Pass	Fail	Caution	Other data

ADCF

ADCF = Air Density Correction Factor, based on tool, altitude (5000'), air temperature through tool

Volumetric flow (CFM 5000') = ADCF x Indicated flow (CFM)

1. House Data

Address		Date of "Residential Mechanical Systems Design Submittal" information referenced	
Builder			

Signatures

Technician #1 performing inspection and testing documented on this report (Approved Agency)

I certify that the tests referenced above, in sections bearing my initials, were performed in accordance with protocols specified by the City of Fort Collins Building Services Department, and that the reported results are accurate to the best of my knowledge.

Name (print)	
Title	
Company	

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Form Sections

2. Measuring Air Pressure + Flow
3. Ventilation Airflow
4. Duct Leakage
5. Furnace / Air Handler
6. Refrigerant Charge
7. Room Pressure Balance + Air flow
8. Combustion Safety
9. Controls

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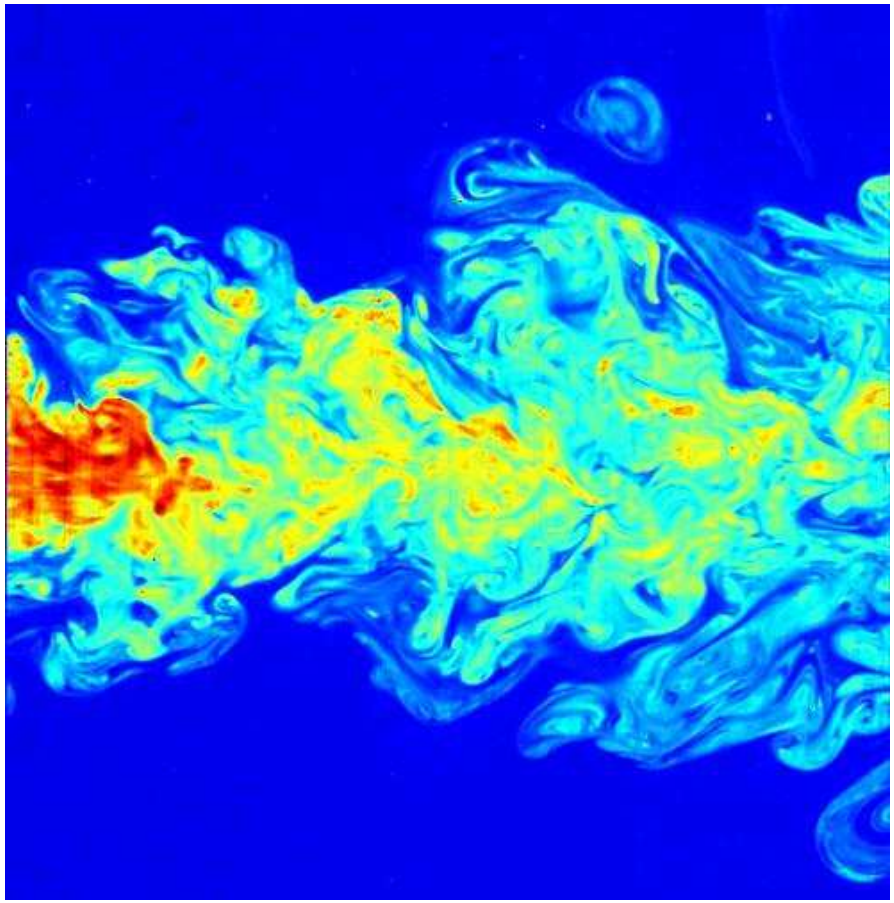
Measuring Air Pressure + Flow

- Pressure
- Flow
- Density Correction
- Flow Types
- Where to Measure?
- Accuracy



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Manometer

Measures a pressure DIFFERENCE

Simple device

- $
- Pressure only

Smart device

- $$
- Microcomputer
- Multifunction
- Can convert P to CFM
- Time average

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Measuring Pressure Difference

- "With Respect To" (wrt)
- Boundary or plane
- Examples
  - Room wrt core of house
  - House wrt outside

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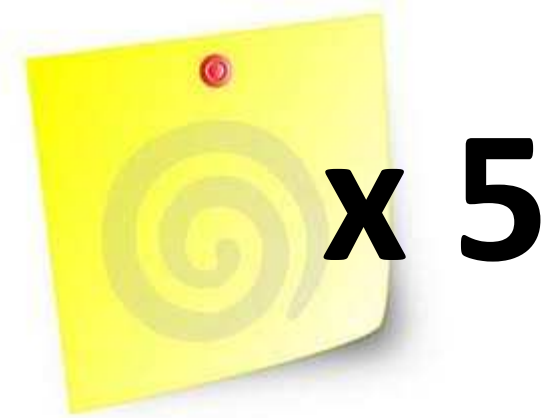
Pressure Units

Pascal (Pa)

- Metric
- Post-It note
- Car tires
  - 6895 Pascals = 1 psi
  - 35 psi = 241325 Pa
- Small but powerful
  - Back-drafting
  - Pressure drive



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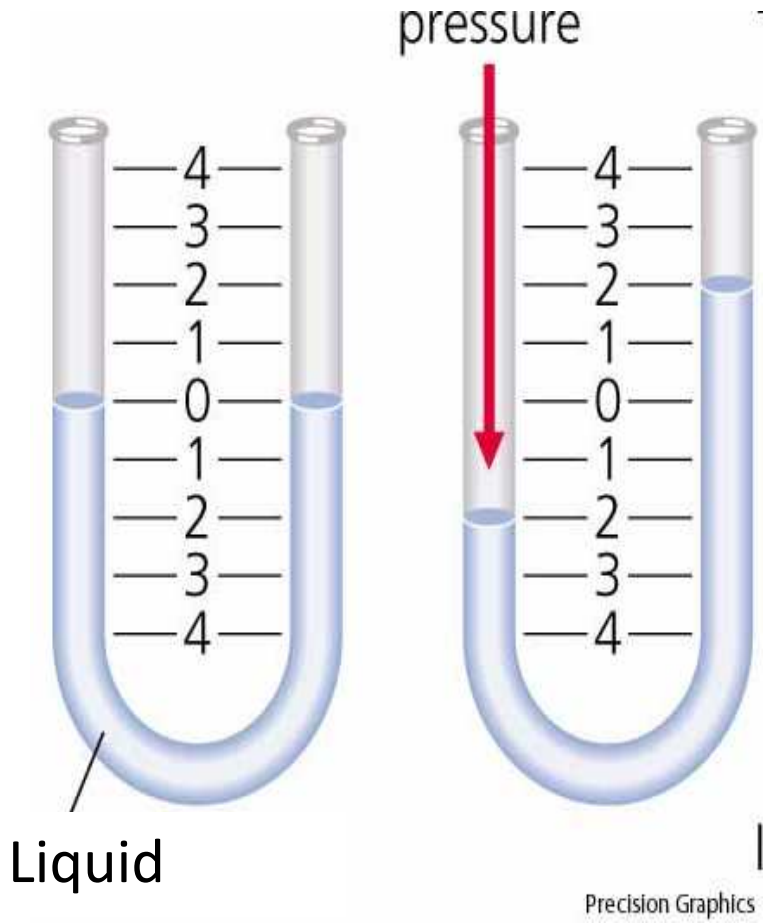
Pressure Units

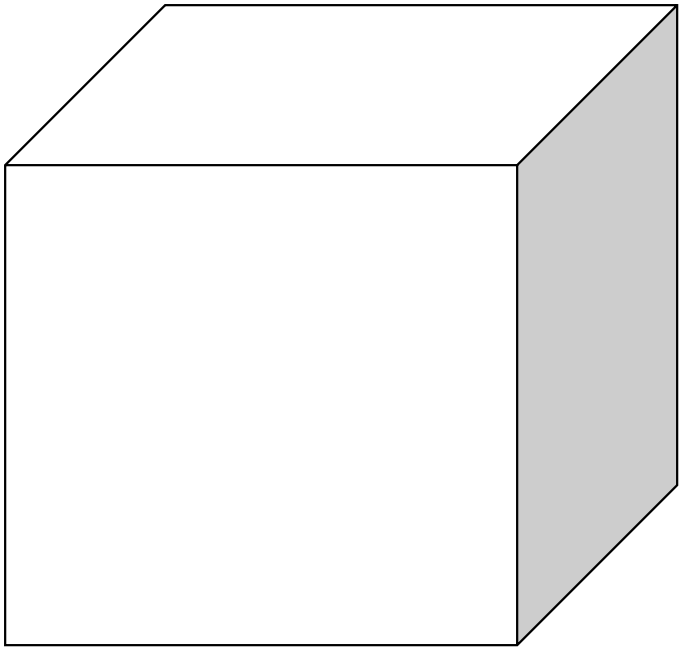
Inch of water column (IWC)

- USA
- Larger
- HVAC

1.0 IWC ~ 250 Pa



Air is Challenging to Measure



Compressible gas

Density varies with temperature + pressure

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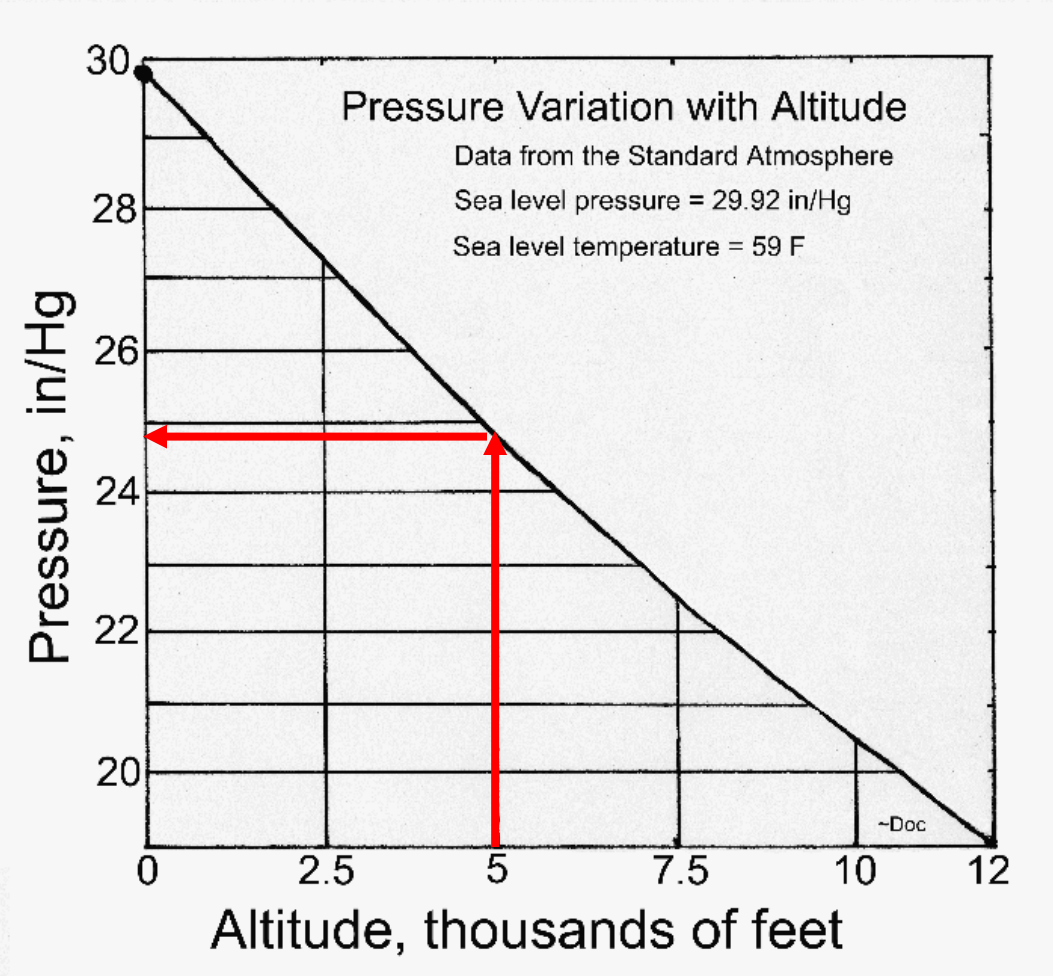
Pressure and Altitude



Standard Atmosphere

Pressure (inches of Hg)

Sea level 29.92

5000’ ~24.9

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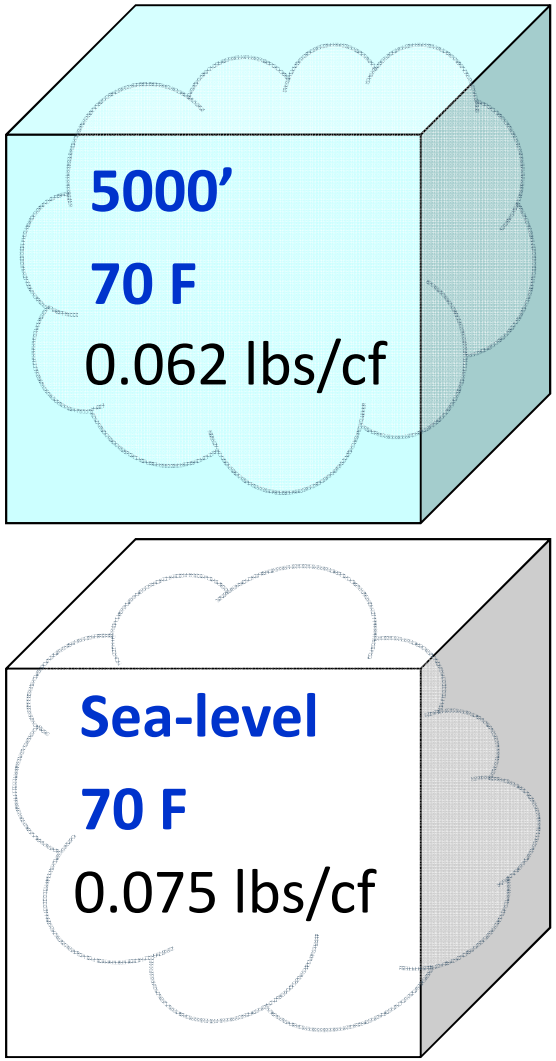
Air at Altitude



1 Cubic Foot of Air

At altitude: ELEV 4984 FT

- Same volume
- Lower density
- Less mass

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Example Pressure → Flow Chart

Plate Pressure	Plate #14	Plate #20
(Pascals)	(CFM)	(CFM)
10	364	487
11	381	511
12	398	533
13	415	555
14	430	576
15	445	596
16	460	616
17	474	635
18	488	653
19	501	671
20	514	689
21	527	706
22	539	722

- Specific to manufacturer and tool
- Check units
- **Read manual, including fine print**

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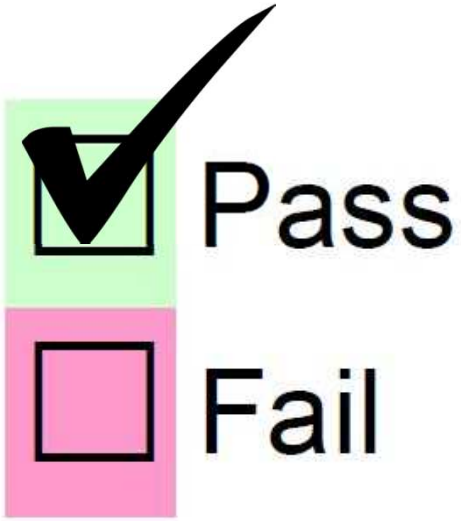
Air Density Variation

Why is this important for HVAC?

- Affects design
- Affects performance
- **Affects measurements**

May make difference between "Pass" and "Fail"!



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Measurement Air Density Correction

- Convert "*Indicated flow*" to "*Volumetric flow*"
- Based on temperature / altitude / air pressure
- Typical: **Volumetric flow = Constant x Indicated flow**
- Conversion constant specific to manufacturer and tool
  - All TEC tools use Table C.1.c : TrueFlow plate, Exhaust Fan Flow Box, Duct Blaster, Flow Blaster
  - Also applies to **Nailor** flow collars
- **Read manual, including fine print**

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Example Conversion Chart

Table C.1.c: **Air Density Factors to Convert from *Indicated* Flow to *Volumetric* Flow.**

Temp. of air through the Metering Plate (F)	Elevation (feet)										
	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
0	0.933	0.950	0.968	0.986	1.005	1.023	1.043	1.062	1.083	1.104	1.125
10	0.943	0.961	0.978	0.996	1.016	1.034	1.054	1.074	1.095	1.116	1.138
20	0.953	0.971	0.989	1.007	1.026	1.045	1.065	1.085	1.106	1.128	1.150
30	0.963	0.981	0.999	1.017	1.037	1.056	1.076	1.097	1.118	1.139	1.162
40	0.973	0.991	1.009	1.028	1.048	1.067	1.087	1.108	1.129	1.151	1.173
50	0.983	1.001	1.019	1.038	1.058	1.077	1.098	1.119	1.140	1.162	1.185
60	0.992	1.010	1.029	1.048	1.068	1.088	1.108	1.130	1.152	1.174	1.197
70	1.002	1.020	1.039	1.058	1.078	1.098	1.119	1.140	1.163	1.185	1.208
80	1.011	1.030	1.049	1.068	1.089	1.109	1.130	1.151	1.174	1.196	1.219
90	1.021	1.039	1.058	1.078	1.099	1.119	1.140	1.162	1.184	1.207	1.231
100	1.030	1.049	1.068	1.088	1.109	1.129	1.150	1.172	1.195	1.218	1.242
110	1.039	1.058	1.078	1.097	1.118	1.139	1.161	1.183	1.206	1.229	1.253
120	1.048	1.067	1.087	1.107	1.128	1.149	1.171	1.193	1.216	1.240	1.264
130	1.057	1.076	1.096	1.117	1.138	1.159	1.181	1.203	1.227	1.250	1.275
140	1.066	1.085	1.106	1.126	1.148	1.169	1.191	1.213	1.237	1.261	1.285
150	1.075	1.094	1.115	1.135	1.157	1.178	1.201	1.224	1.247	1.271	1.296

Volumetric Flow = Indicated Flow x Sqrt (0.075/air density) where air density is the density of air, in lbs/ft^3, going through the Metering Plate.

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Example Conversion Chart

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Volumetric Flow = Indicated Flow x Sqrt (0.075/air density) where air density is the density of air, in lbs/ft^3, going through the Metering Plate.

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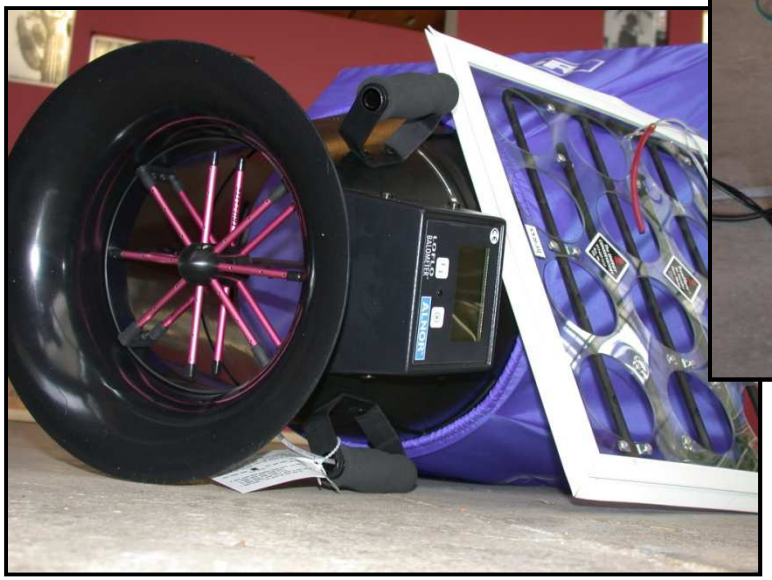
Toolbox



- If all else fails . . . read manual!
- Calibration

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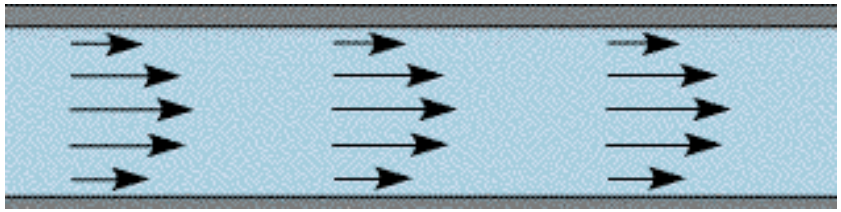
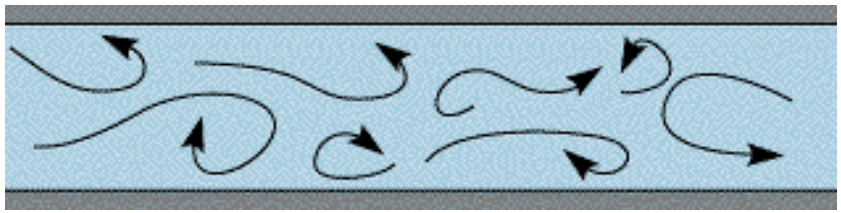
Types of Flow

Laminar



Turbulent



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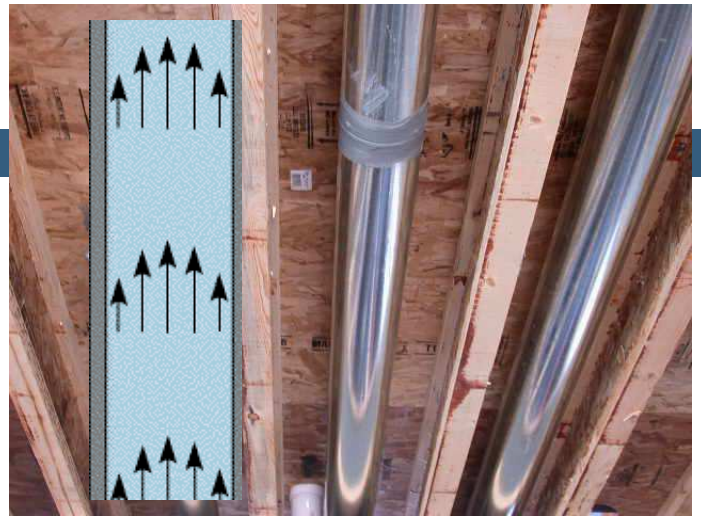
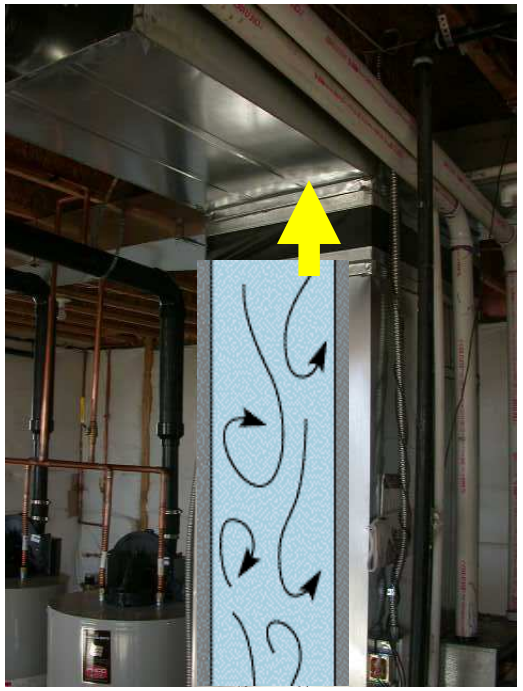
Where to Measure?



Ideal

- Well-developed, laminar flow
- Several diameters downstream from fittings / bends / transitions



Reality

- Think about where you measure
- Will turbulence be a problem?
- Do the best you can

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How Accurate Do We Need to Be?

- **Accurate enough to draw useful conclusions**
  - Know why you are measuring
  - Know what you are measuring
- **The sniff test**
  - Know what you are expecting
  - Are the results reasonable?
- **Repeatability**

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Manometer Demo

- Measures quantities?
  - Pressure
  - Velocity
  - Flow
- For multiple tools
  - Duct Blaster
  - TrueFlow grid
  - Pitot tube
  - . . .
- How is tool configured?
  - Opening size
- Time averaging?

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2. Ventilation

Spot Ventilation

Whole-House Ventilation

It's There,
Does it Work?

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Spot Ventilation (Local Exhaust)

Remove pollutants near their source

Simple system

- Fan
- Duct
- Termination
- Control

Can also be used as whole house ventilation

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2012 IRC/IMC + Fort Collins Amendments

IRC M1309 Testing and verification

Bathrooms

- If required meet code minimum flow rate
- Test all fan flows
- If WH ventilation meet min & design flow rate
  - Requires occupant control
  - 1.5 sone or <

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2012 IRC/IMC

M1507.3 Exhaust Ventilation

Spot ventilation

Location	Code Minimum Exhaust Rates
Baths	50 CFM intermittent 20 CFM continuous
Kitchens: code min if vented to outside	100 CFM intermittent 25 CFM continuous

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Amendment: gas cooking venting

- Hood must vent outside.
- > 400 cfm requires makeup air
- Makeup air must ~ equal exhaust flow rate
- Makeup air interlocked

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EXHAUST FAN FLOW MEASUREMENT DEMONSTRATION

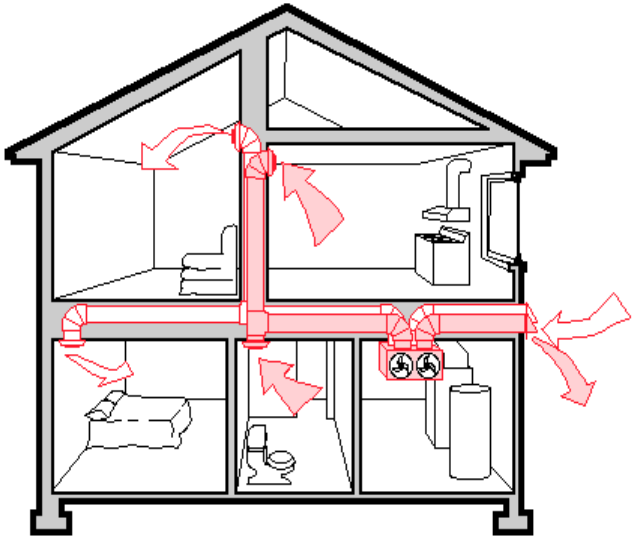
Let’s regroup in the bathroom

3. Whole-Dwelling Unit Ventilation

- Find Code-Min / Design Flow rate from Submittal
- Exhaust/ Supply /Balanced:

  Target Range = Code-min to 120% of design flow

  Measurement & Pass/ Fail
- Balanced: supply & exhaust flows within +/- 15% average
- Sub-floor exhaust: exhaust flow within 15% of design



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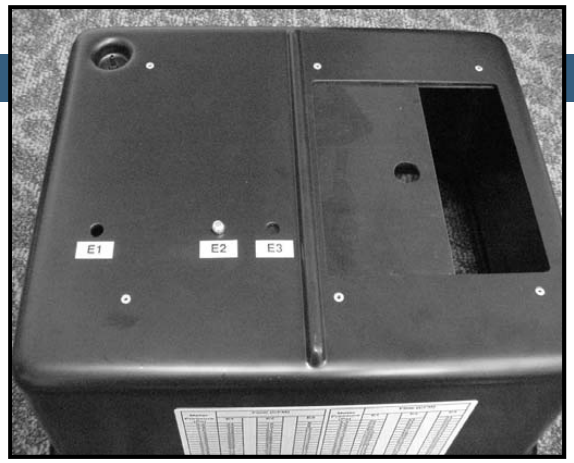
Tool Options

Considerations

- Flow direction
- Low airflow rates
- Location
- Wind
- Cost
- Accuracy
- Redundant measurements
- Sniff test



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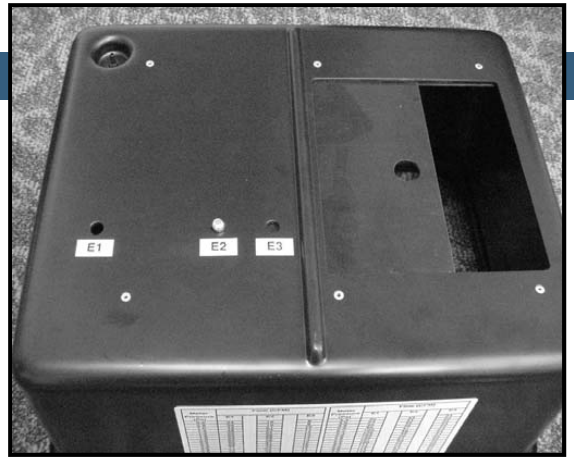
Tool Options

- Exhaust flow
  - Flow hood
  - Flow box
- Supply flow
  - Duct traverse
  - Flow collar
- Balanced system
  - Depends
  - Combo



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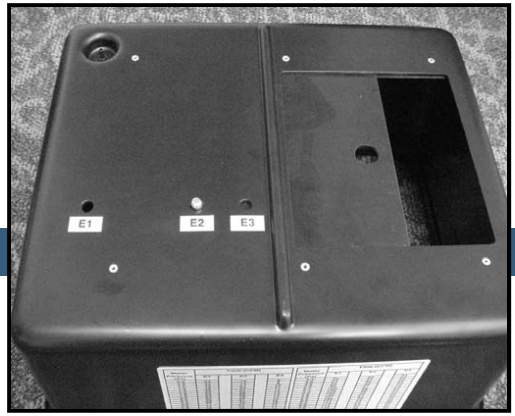
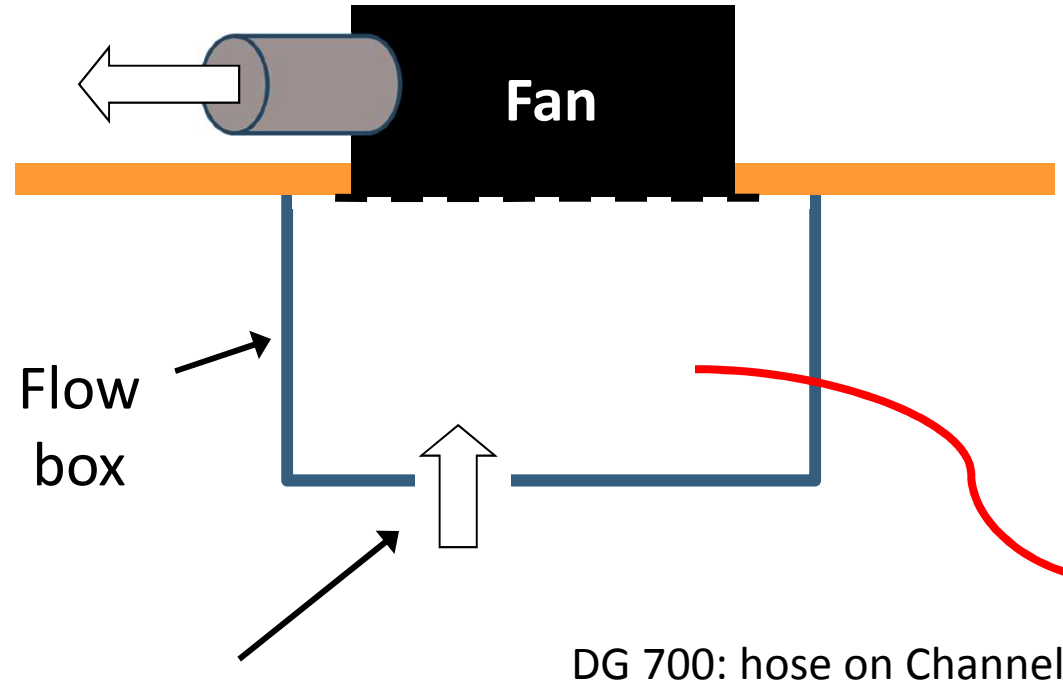
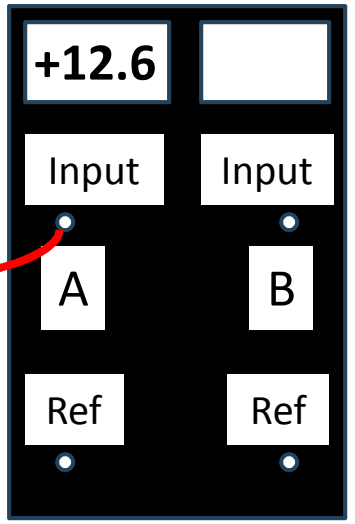
Flow Box (Read Manual)





Select flow range opening. Config DG to door position



DG 700: hose on Channel A : Pressure, B shows air flow. Manometer: shows press; convert to flow with chart

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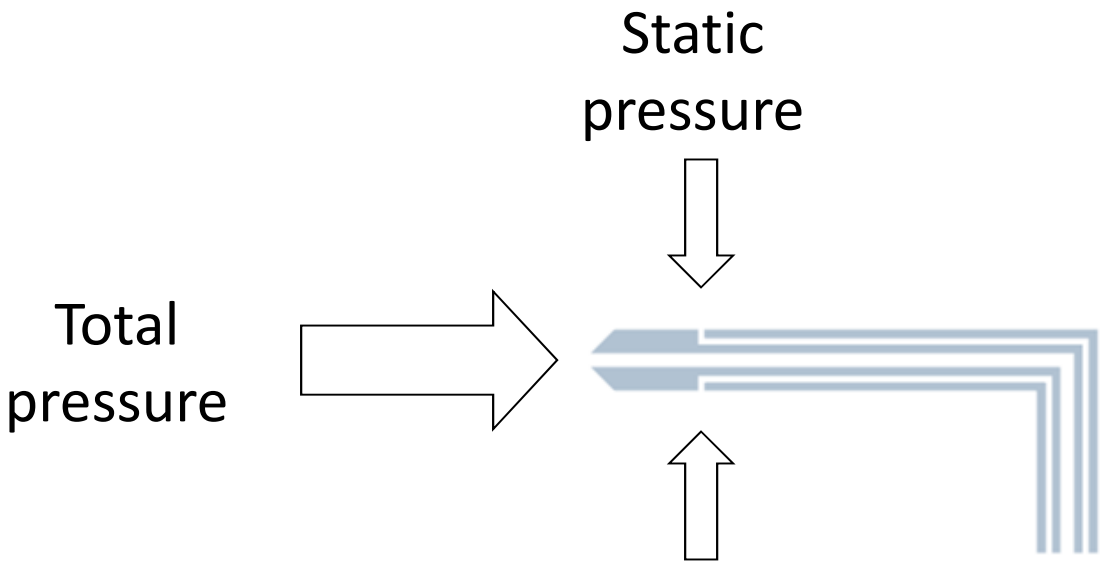
Pitot Tube Anemometer



Velocity pressure = (Total pressure) – (Static pressure)

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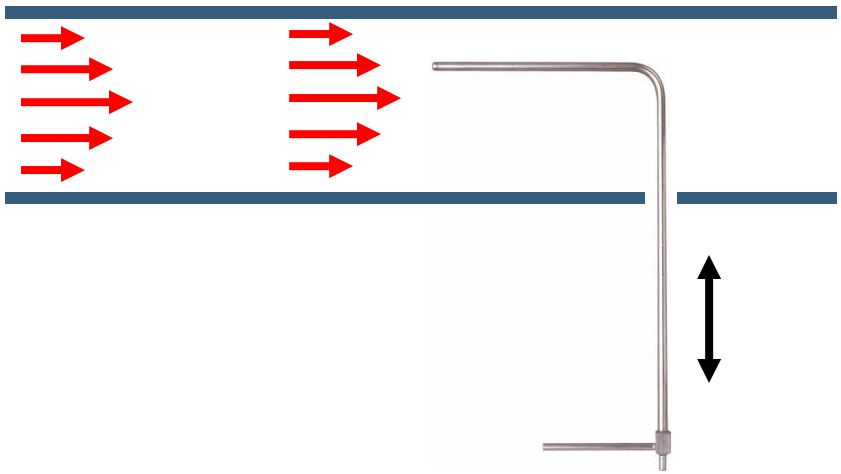
Pitot Tube Anemometer



Flow = (Average velocity) x Area x ADCF

Average velocity:

Average of 3-point traverse

or ~ 0.9 x (Centerline velocity)

Laminar flow

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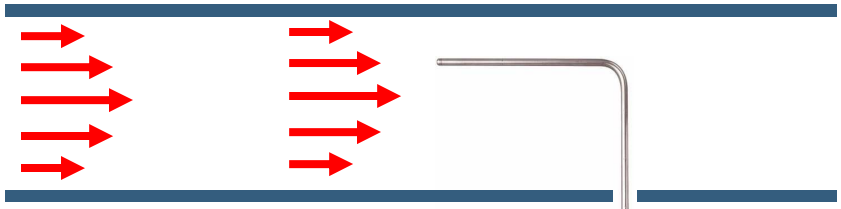
Pitot Tube Anemometer



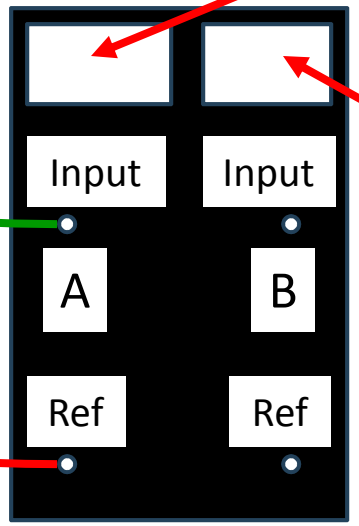
Set DG 700
Mode to PR/ V

Velocity pressure

Total pressure

Velocity of flow

Static pressure



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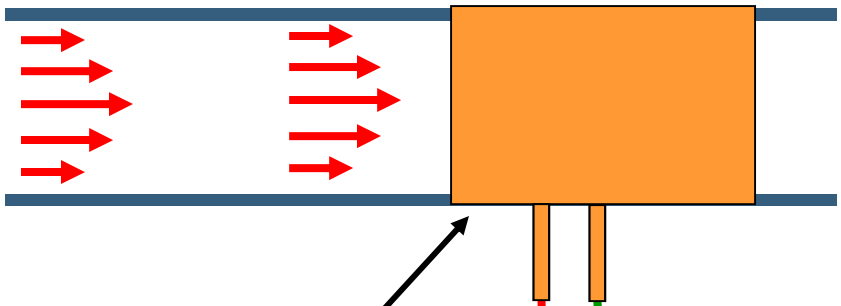
Flow Collar (Nailor)



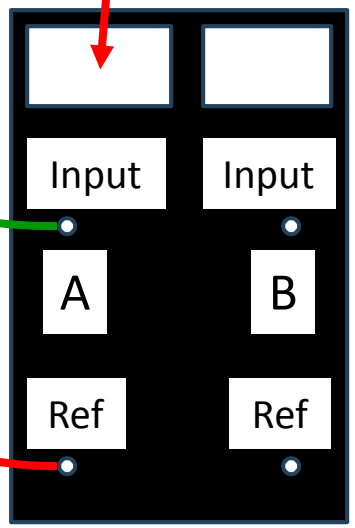
Flow collar (grid of total + static pressure sensors)

Average total pressure

Average static pressure

Read velocity pressure

Convert velocity pressure drop to flow with table on collar



Set DG 700 Mode to Pr/ V

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WHOLE HOUSE VENTILATION AIRFLOW MEASUREMENT DEMONSTRATION

Bring you manometers

4. Duct Leakage Testing

Total Duct Leakage

Test if ducts outside thermal boundary (attic)

Test at Rough- in or Completion

City of Fort Collins

2012 IRC/IECC

IECC 403.2.2 Duct Sealing

Three ways to test – pick one

Note: Leakage to outside metric no longer used

Test Type	Stage	Air Handler	Max Leakage CFM25/100 sf	Example: 2000 sf house
Total leakage	Rough	Excluded	3	60 CFM25
Total leakage	Rough	Included	4	80 CFM25
Total leakage	Complete	Included	4	80 CFM25

City of Fort Collins

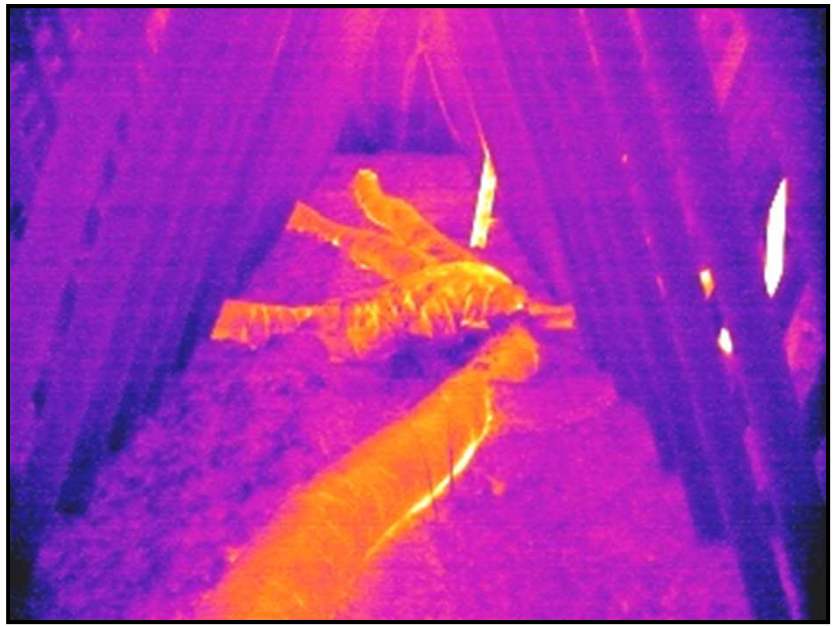
2012 IRC/IECC

IECC 403.2.2 Duct Sealing

Mandatory:

Leakage testing required when <u>any portion</u> of ductwork is in unconditioned space

- Attic
- Crawl space outside thermal envelope
- Isolated mechanical room with natural draft appliance
- Floor over garage



City of Fort Collins

2009 IRC/IECC

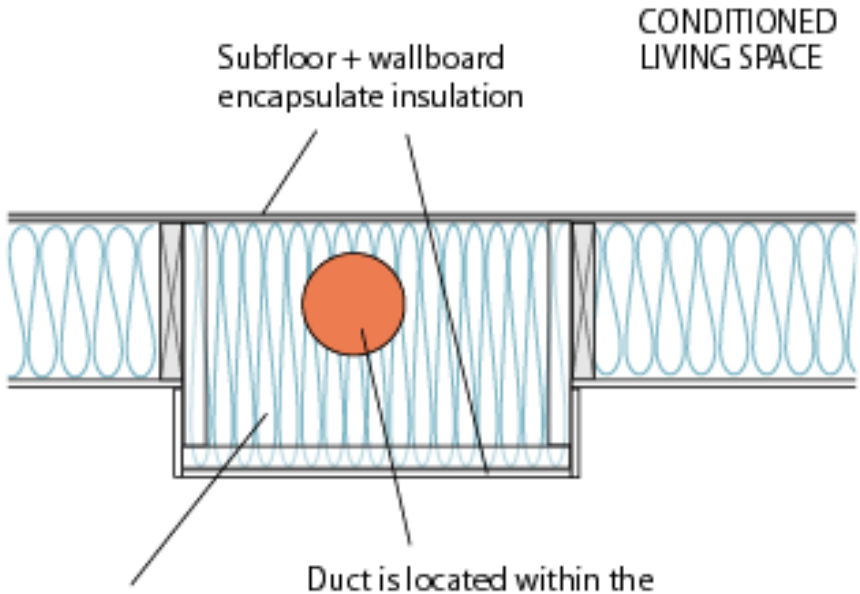
IECC 403.2.2 Duct Sealing

Ductwork inside or out?

- Exterior wall
- Floor over garage

Where is the thermal boundary?

- Always better to be inside
- Details matter
- Refer to handouts



Testing Protocols

RESNET 803

Equipment + supplies

- Duct tester
- Manometer
- Materials to temporarily seal duct openings

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Total Duct Leakage

- Decide + or – test: + at rough and – at final?
- Where to install tester?
  - Multi-returns: attach to air handler cabinet
  - Air handler in attic or large central return
    - Attach flex duct to large wall or ceiling return
- Use flex duct or not
  - Install round to fan inlet for – test,
  -

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Total Duct Leakage

- Disable furnace & any exhaust fans
- Remove furnace filter
- Block off all supply + return grilles
- Ventilation supply duct
  - Close motorized damper
  - Do not seal opening
- Do not seal ventilation air into return plenum
  - Damper closed

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Total Duct Leakage

- Ducts in attic: open scuttle
- Install duct reference static pressure tap
  - Always on supply side
  - At least 10 ft from supply plenum
  - Tip faces toward airflow

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Total Duct Leakage

- Set up DG700 gauge
  - Ref hose to A input, Fan to B input
- Turn on duct tester fan, adjust speed
- Duct test pressure + or - 25 Pa
- Walk house, check masking
- Re-check reference pressure
- Measure airflow through duct tester

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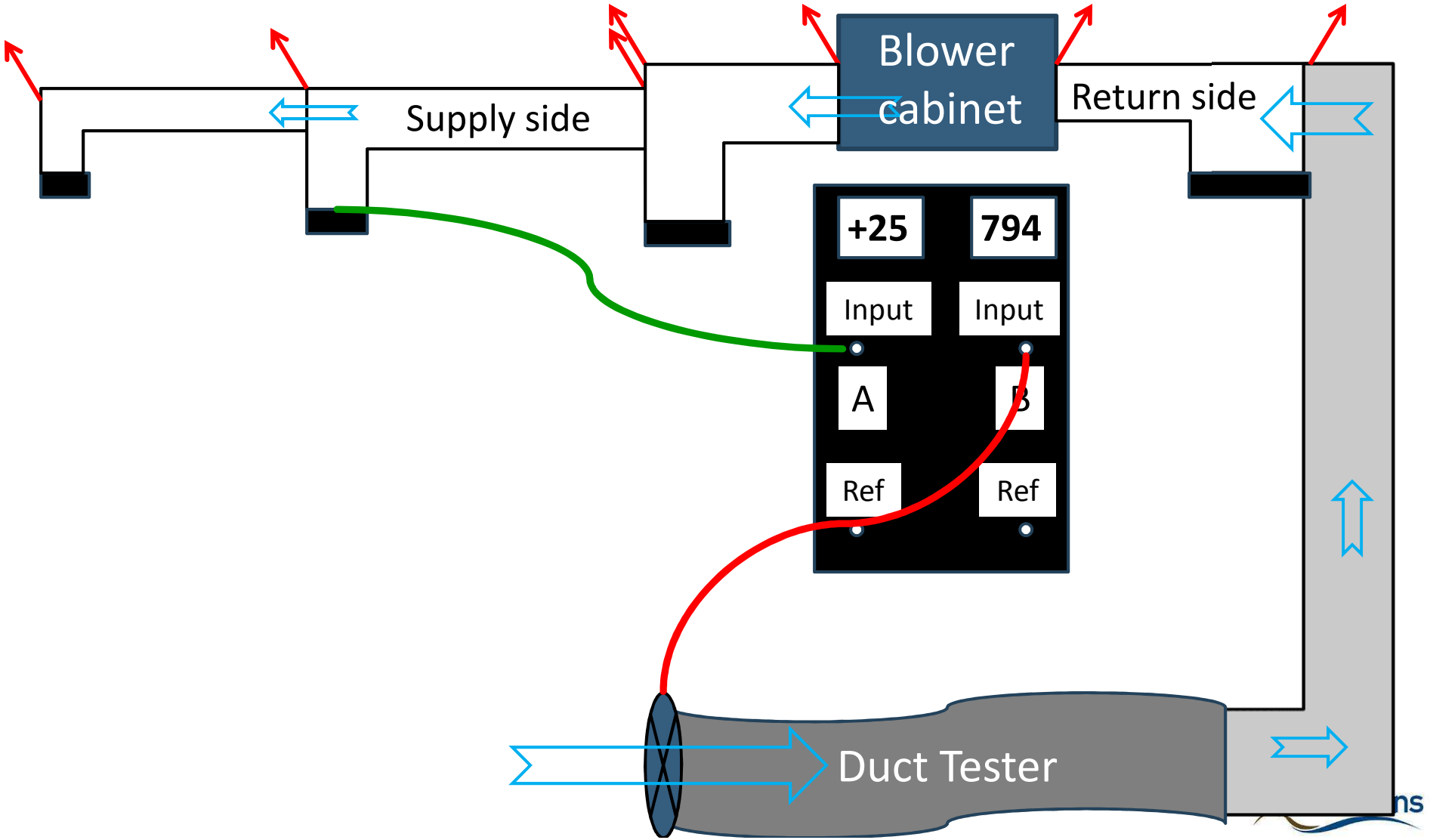
Total Duct Leakage



Total Duct Leakage

Flow Conversion Table

Fan Pressure (Pascals)	Flow (CFM) Open Fan	Ring 1	Ring 2	Ring 3
4				12
6				15
8				17
10				19
12				21
14				23
16				24
18				26
20				27
22				29
24				30
26	560	209	80	31
28	581	217	83	32
30	602	225	85	34
32	622	232	88	35
34	641	239	91	36
36	660	246	94	37
38	678	253	96	38
40	696	260	99	39
42	713	266	101	40
44	730	273	104	41
46	746	279	106	42
48	762	285	108	43
50	778	291	111	44
52	794	296	113	45

Double-check or using standard manometer

- Change to fan pressure on Channel B
- Use pressure → flow chart

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Total Duct Leakage

Low fan pressure

- If fan pressure less than or equal to 20 Pascals, add constricting ring
- Set gauge to match

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Total Duct Leakage

Leaky ducts

- Duct pressures tend **NOT** to be uniform
- Reference pressure tap placement affects results
- Really leaky systems: consider testing twice, averaging results

Tight ducts

- Duct pressures tend to be uniform
- Reference pressure tap placement less critical
  - Trunk-line
  - Supply boot

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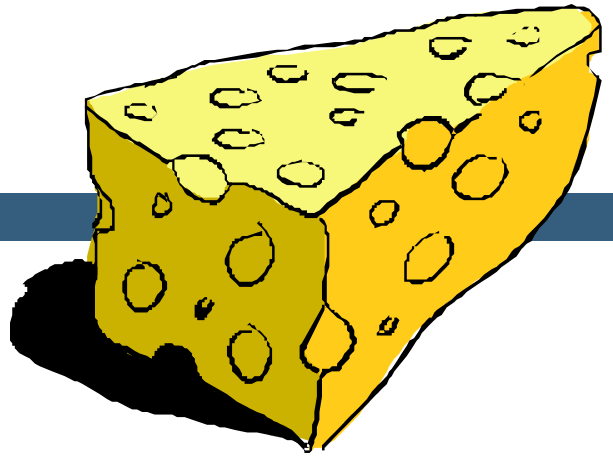
Total Duct Leakage



Leaky ducts & Air Handler?

If can't hit 25 Pa, adjust results:

CFM25 = max fan flow x (25 Pa / max duct pressure)$^{0.6}$

Air Handler cabinet leakage cannot be > 2% system flow

City of Fort Collins

DUCT LEAKAGE TESTING DEMONSTRATION

Meet at the Furnace

5. Furnace / Air Handler

Code-Required Testing

Verify Heating & Cooling Equipment spec'd in Design was installed

OEM Specifications

Design Targets

City of Fort Collins

2012 IRC/IMC + Fort Collins Amendments

IRC M1309 Testing and verification

Is it there: was specified equipment installed?

- Equipment + ductwork: **does it work** as intended
- Heating (high-heat stage)
  - Manifold gas pressure
  - Temperature rise
- Cooling
  - Airflow at indoor coil
  - Refrigerant charge

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Design Targets

Find targets in design submittal

- Ext Static pressure
- Gas Pressure
- Temp Rise
- Airflow through air handler
  - Cooling
- Control strategy

Cooling Equipment Summary

Make	Carrier		
Trade	BASE 13 PURON AC		
Cond	24ABB324C30		
Coil	CNPV*2414A**		
AHRI ref no.	3040365		
Efficiency	11.7 EER, 14 SEER		
Sensible cooling		20205	Btuh
Latent cooling		2755	Btuh
Total cooling		22960	Btuh
Actual air flow		1340	cfm
Air flow factor		0.076	cfm/Btuh
Static pressure		0.70	in H2O
Load sensible heat ratio		1.00	

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Testing Tips

- Clean filter, same as delivered with house
- All registers open
- Fan speed correct for each test
  (set at heating, cooling, continuous fan?)
- Read the manuals: equipment and test equipment

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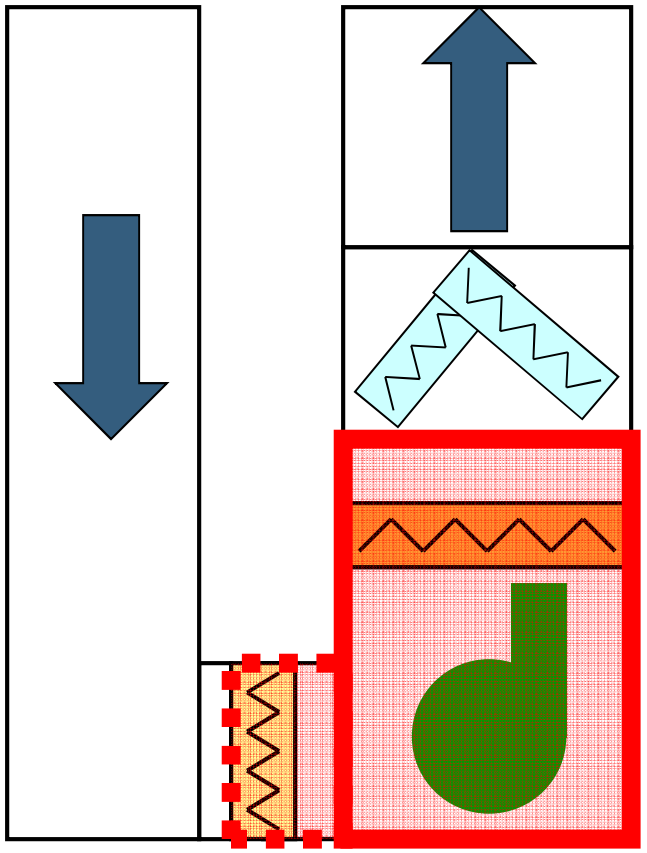
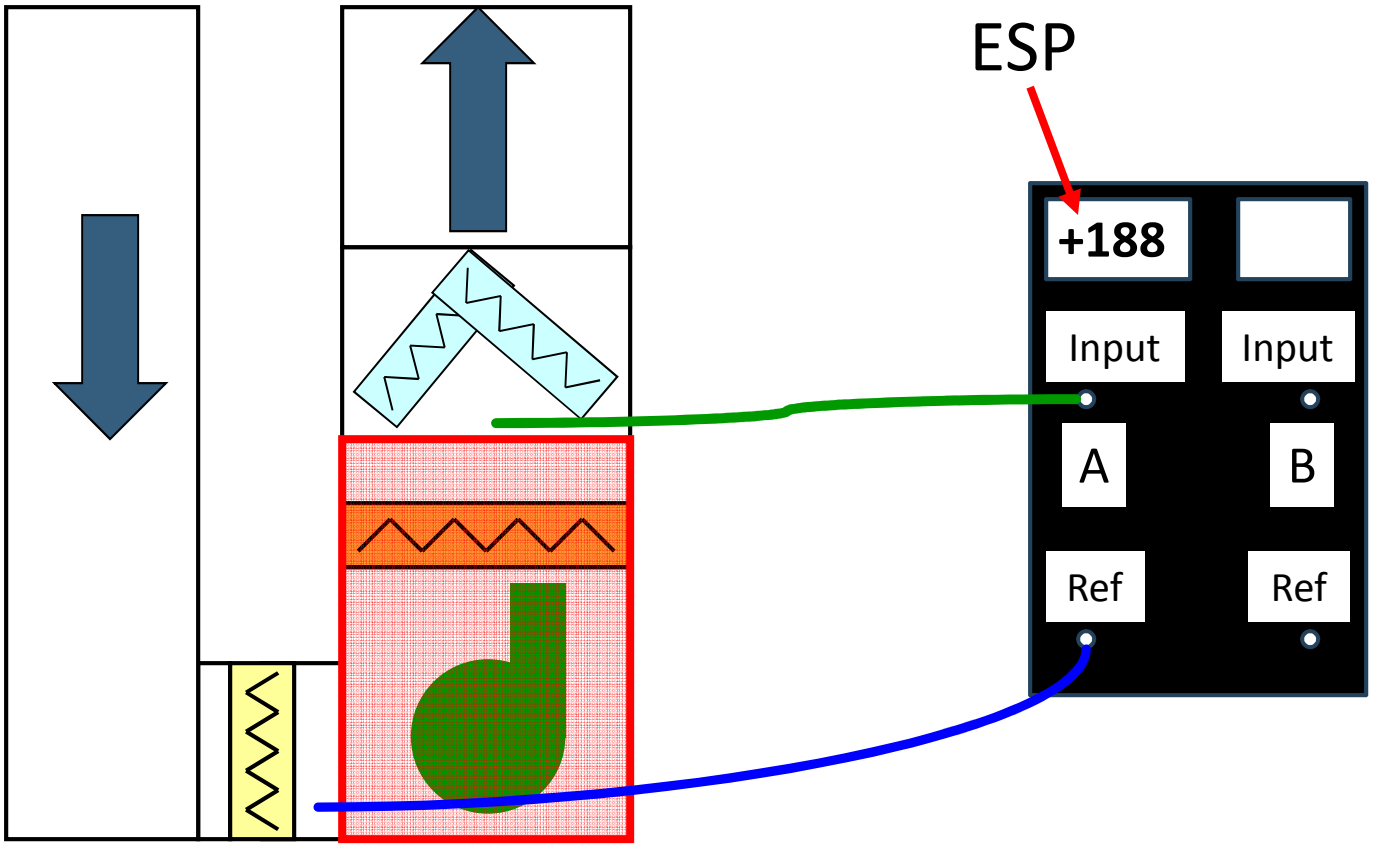
External Static Pressure

External Static Pressure (ESP)

- Everything outside the furnace box
- Filter sometimes included



External Static Pressure



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Air Handler OEM Specs

Blower Performance

Carrier 58MCB

AIR DELIVERY-CFM (WITH FILTER)*

UNIT SIZE	RETURN-AIR SUPPLY	SPEED	EXTERNAL STATIC PRESSURE (In. wc)							
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
040-08	1 side or bottom	High Med-Low Low	1075 850 740	1040 825 700	995 780 650	945 740 620	895 685 565	840 635 515	760 560 455	670 480 385
040-12	1 side or bottom	High Med-High Med-Low Low	1470 1315 1125 930	1415 1280 1110 925	1400 1235 1085 910	1285 1180 1045 850	1215 1115 990 830	1120 1035 915 770	995 930 830 705	890 825 740 635
060-08	1 side or bottom	High Med-Low Low	1100 890 745	1065 865 710	1005 810 670	945 765 625	900 705 565	805 620 505	730 540 425	610 475 360
060-12	1 side or bottom	High Med-High Med-Low Low	1430 1270 1070 915	1375 1260 1055 895	1325 1215 1045 885	1275 1160 1015 865	1200 1105 975 840	1135 1035 920 800	1040 950 850 720	935 850 750 650
060-16	1 side or bottom	High Med-High Med-Low Low	1700 1500 1325 1205	1695 1465 1295 1170	1640 1435 1265 1145	1580 1385 1230 1110	1545 1355 1190 1080	1450 1300 1150 1035	1380 1250 1105 990	1310 1185 1050 950
080-12	1 side or bottom	High Med-High Med-Low Low	1535 1395 1200 1040	1470 1350 1175 1020	1405 1300 1125 990	1330 1225 1065 960	1245 1155 1030 910	1160 1080 970 860	1065 985 890 785	935 880 780 680
080-16	1 side or bottom	High Med-High Med-Low Low	1750 1495 1310 1135	1685 1455 1260 1105	1635 1405 1225 1075	1575 1355 1170 1040	1525 1305 1125 995	1445 1250 1095 995	1380 1185 1040 910	1310 1120 980 860

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Measuring Airflow Using A True Flow Grid

The Energy Conservatory's True Flow Grid is an air measuring device used to calculate airflow through the air handler in real time by:
1) measuring the normal static pressure,
2) replacing the filter with the grid 3) re-measuring the system pressure and flow through the grid.

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Measuring Airflow Using A True Flow Grid

- Locate filter and replace it if dirty.
- Install static pressure probe into duct work, in one of three suggested locations
- Connect the probe to the DG700 input tap on Channel “A”

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Set Up The Gauge

- Turn on the meter and the air handler
- Follow testing direction from the Energy Conservatory's Quick Guide TF2
- Turn off the air handler when you've acquired the NSOP for the system

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Install True Flow Metering Plate

- Remove the filter
- With Grid 14 or 20 and the spacers, match to the size of the filter slot
- Install the assembly with the diamonds on the face upstream into the air flow, away from the air handler
- Close or tape over access doors

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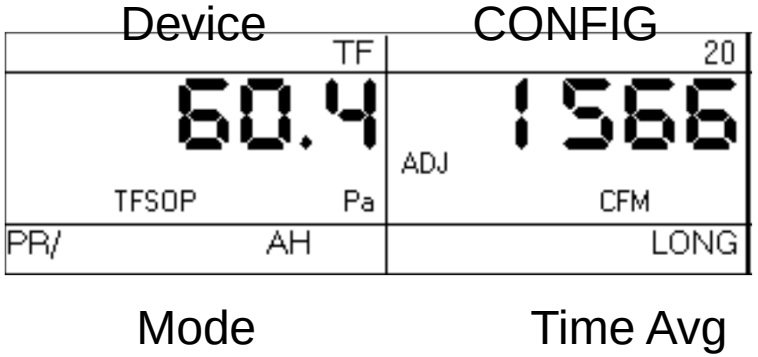
Set up the DG700

- Red tube to Channel B input Tap
- Green tube to Channel B reference tap
- Set Device to **TF**
- Config. to match Grid 14 or 20
- Turn on the air handler

(TFSOP) True Flow System Operating Pressure & Adj. Total Air Handler Flow

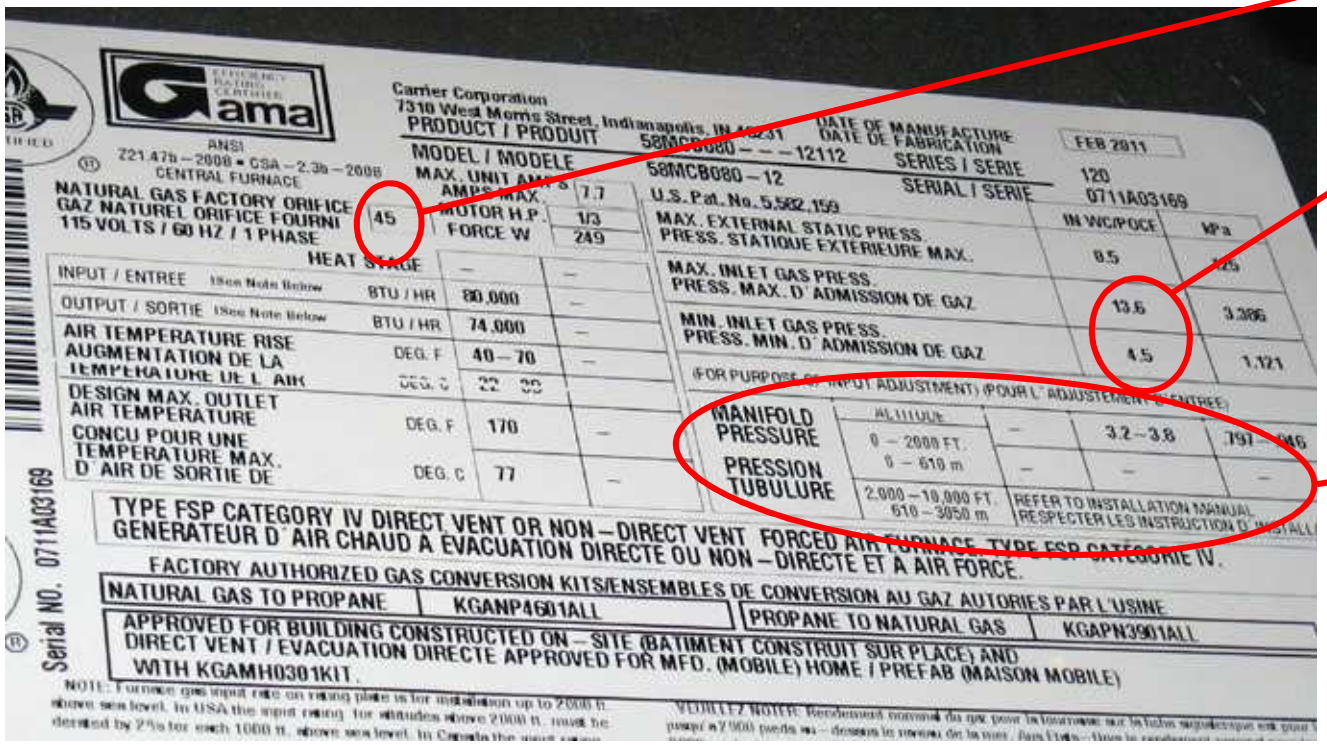
- TFSOP reading in Pascal's on Channel A
- Total Air Handler flow in CFM on Channel B
- This is the air flow of the system with the existing filter in place
- Turn off the air handler



Gas Furnace OEM Specs

Gas Pressure

Gas pressure target – not as straightforward



Factory orifice: 45

Inlet gas pressure: 4.5 to 13.6 IWC

Manifold gas pressure:

2000' +

Refer to installation manual

Gas Furnace OEM Specs

Gas Pressure

Table 14 – Model 58MCB Orifice Size and Manifold Pressure for Correct Input

FOR USE WITH 040 THROUGH 120 SIZE FURNACES ONLY

(TABULATED DATA BASED ON 20,000 BTUH PER BURNER, DERATED 2%/1000 FT (305M) ABOVE SEA LEVEL)

ALTITUDE RANGE ft (m)		AVG. GAS HEAT VALUE AT ALTITUDE (Btu/cu ft)	SPECIFIC GRAVITY OF NATURAL GAS							
			0.58		0.60		0.62		0.64	
			Orifice No.	Manifold Pressure	Orifice No.	Manifold Pressure	Orifice No.	Manifold Pressure	Orifice No.	Manifold Pressure
U.S.A. Only		750	43	3.7	43	3.8	42	3.2	42	3.3
	4001	775	43	3.5	43	3.6	43	3.7	43	3.8
	(1220)	800	44	3.7	43	3.4	43	3.5	43	3.6
	to	825	44	3.5	44	3.6	44	3.7	43	3.4
		850	44	3.3	44	3.4	44	3.5	44	3.6
	5000	875	**45**	**3.8**	44	3.2	44	3.3	44	3.4
	(1524)	900	**45**	**3.6**	**45**	**3.7**	**45**	**3.8**	44	3.2
		925	**45**	**3.4**	**45**	**3.5**	**45**	**3.6**	**45**	**3.7**
U.S.A. Only		725	43	3.6	43	3.8	42	3.2	42	3.3
	5001	750	43	3.4	43	3.5	43	3.6	43	3.8
	(1525)	775	44	3.7	44	3.8	43	3.4	43	3.5
	to	800	44	3.4	44	3.6	44	3.7	44	3.8
		825	44	3.2	44	3.3	44	3.4	44	3.6
	6000	850	**45**	**3.7**	**45**	**3.8**	44	3.2	44	3.4
	(1829)	875	**45**	**3.5**	**45**	**3.6**	**45**	**3.7**	**45**	**3.8**
		900	**45**	**3.3**	**45**	**3.4**	**45**	**3.5**	**45**	**3.6**

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Gas Furnace OEM Specs

Gas Pressure

Table 14 – Model 58MCB Orifice Size and Manifold Pressure for Correct Input

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			Orifice No.	Manifold Pressure	Orifice No.	Manifold Pressure	Orifice No.	Manifold Pressure	Orifice No.	Manifold Pressure
U.S.A. Only	4001 (1220) to 5000 (1524)	750	43	3.7	43	3.8	42	3.2	42	3.3
		775	43	3.5	43	3.6	43	3.7	43	3.8
		800	44	3.7	43	3.4	43	3.5	43	3.6
		825	44	3.5	44	3.6	44	3.7	43	3.4
		850	44	3.3	44	3.4	44	3.5	44	3.6
		875	**45**	**3.8**	44	3.2	44	3.3	44	3.4
		900	**45**	**3.6**	**45**	**3.7**	**45**	**3.8**	44	3.2
		925	**45**	**3.4**	**45**	**3.5**	**45**	**3.6**	**45**	**3.7**
U.S.A. Only	5001 (1525) to 6000 (1829)	725	43	3.6	43	3.8	42	3.2	42	3.3
		750	43	3.4	43	3.5	43	3.6	43	3.8
		775	44	3.7	44	3.8	43	3.4	43	3.5
		800	44	3.4	44	3.6	44	3.7	44	3.8
		825	44	3.2	44	3.3	44	3.4	44	3.6
		850	**45**	**3.7**	**45**	**3.8**	44	3.2	44	3.4
		875	**45**	**3.5**	**45**	**3.6**	**45**	**3.7**	**45**	**3.8**
		900	**45**	**3.3**	**45**	**3.4**	**45**	**3.5**	**45**	**3.6**

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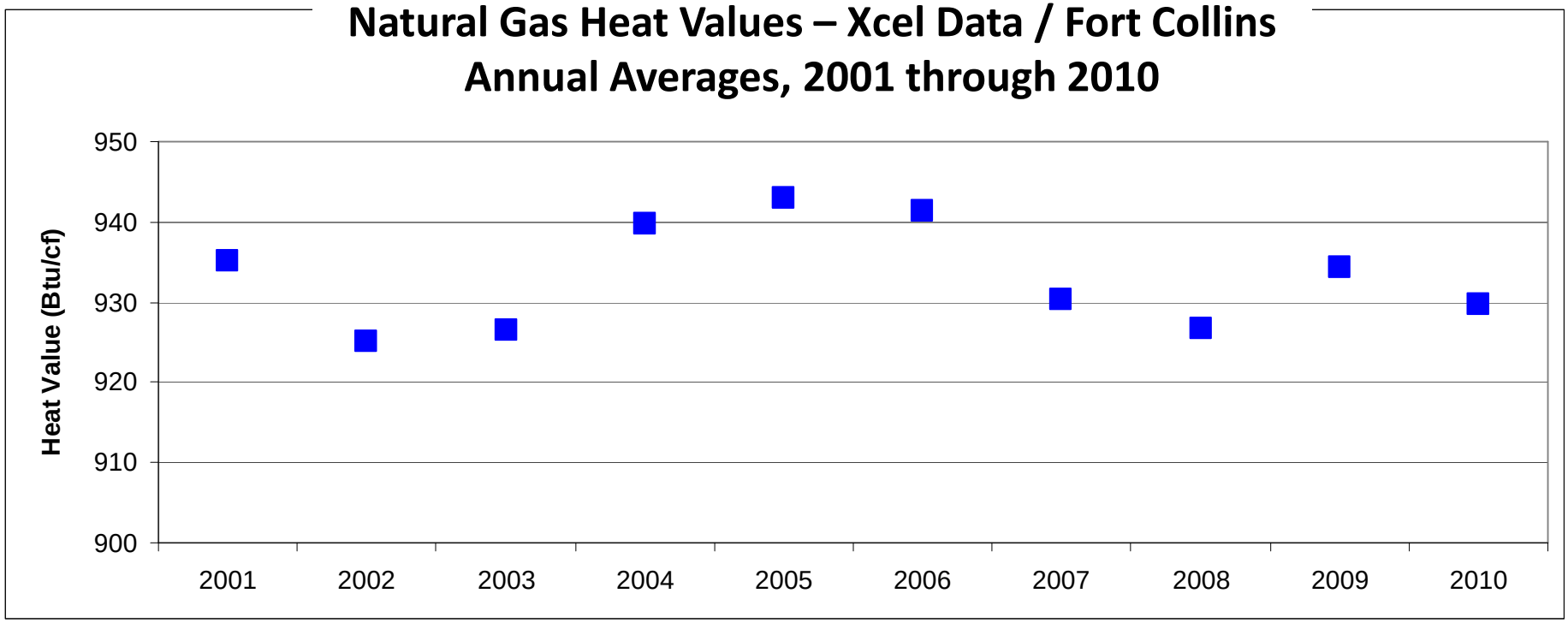
Gas Furnace OEM Specs

Gas Pressure



Annual averages range: ~ 925 to 945 Btu/cf

(Monthly values range: ~ 880 to 990 Btu/cf)

Gas Furnace OEM Specs

Gas Pressure

Table 14 – Model 58MCB Orifice Size and Manifold Pressure for Correct Input

FOR USE WITH 040 THROUGH 120 SIZE FURNACES ONLY

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		825	44	3.5	44	3.6	44	3.7	43	3.4
		850	44	3.3	44	3.4	44	3.5	44	3.6
		875	**45**	**3.8**	44	3.2	44	3.3	44	3.4
		900	**45**	**3.6**	**45**	**3.7**	**45**	**3.8**	44	3.2
		925	**45**	**3.4**	**45**	**3.5**	**45**	**3.6**	**45**	**3.7**
U.S.A. Only	5001 (1525) to 6000 (1829)	725	43	3.6	43	3.8	42	3.[illegible]	42	3.3
		750	43	3.4	43	3.5	43	3.[illegible]	43	3.8
		775	44	3.7	44	3.8	43	3.4	43	3.5
		800	44	3.4	44	3.6	44	[illegible]	[illegible]	[illegible]
		825	44	3.2	44	3.3	44	[illegible]	[illegible]	[illegible]
		850	**45**	**3.7**	**45**	**3.8**	44	3.2	44	3.4
		875	**45**	**3.5**	**45**	**3.6**	**45**	**3.7**	**45**	**3.8**
		900	**45**	**3.3**	**45**	**3.4**	**45**	**3.5**	**45**	**3.6**

Target 3.6 IWC

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Gas Furnace OEM Specs

Temperature Rise

Carrier 58MCB

SPECIFICATIONS (CONTINUED)

UNIT SIZE			080–16	080–20
Shipping Weight – Lb. (KG)			193 (88)	201 (91)
RATINGS AND PERFORMANCE				
Input Btuh*			80,000	80,000
Output Capacity BTUH* (ICS) (Shaded capacities are specified on rating plate)	Direct Vent (2–Pipe)	Upflow	74,000	74,000
		Downflow	74,000	74,000
		Horizontal	74,000	74,000
	Non–Direct Vent (1–Pipe)	Upflow	74,000	74,000
		Downflow	74,000	74,000
		Horizontal	74,000	74,000
AFUE%† Nonweatherized ICS	Direct Vent (2–Pipe)	Upflow	92.3	92.3
		Downflow	91.2	91.2
		Horizontal	92.1	92.1
	Non–Direct Vent (1–Pipe)	Upflow		
		Downflow		
		Horizontal		
Certified Temperature Rise Range °F (°C)			30–60 (17–33)	20–50 (11–28)
Certified External Static Pressure		Heating	0.15	0.15
		Cooling	0.50	0.50
Airflow CFM‡		Heating	1285	1785
		Cooling	1525	1925

Temp rise

30 to 60 F

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DEMONSTRATE FURNACE CX AND COOLING AIRFLOW

Gather at the furnace

6. Refrigerant Charge

AC Cycle

Subcooling

Superheat

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Charge to Airflow

1. Measure + adjust airflow

2. Test + adjust refrigerant charge

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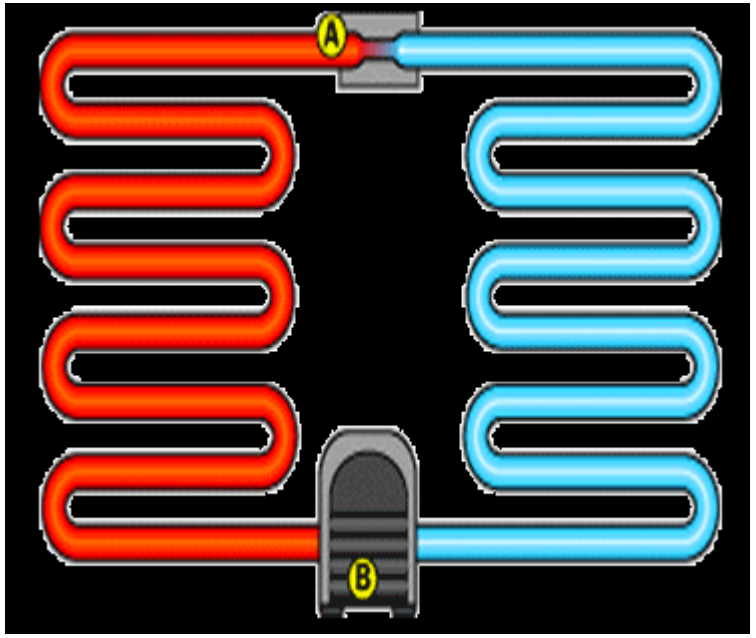
Principles of Refrigeration

- Evaporation: Liquids absorb heat when changed from liquid to gas
- Condensation: Gases release heat when changed from gas to liquid
- Sensible capacity = capacity required to lower the temperature
- Latent capacity = capacity to remove moisture from the air
- Condensation forms on air side of coil as latent heat removed from air



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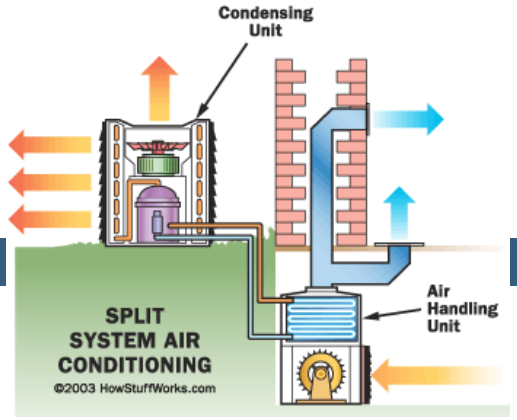
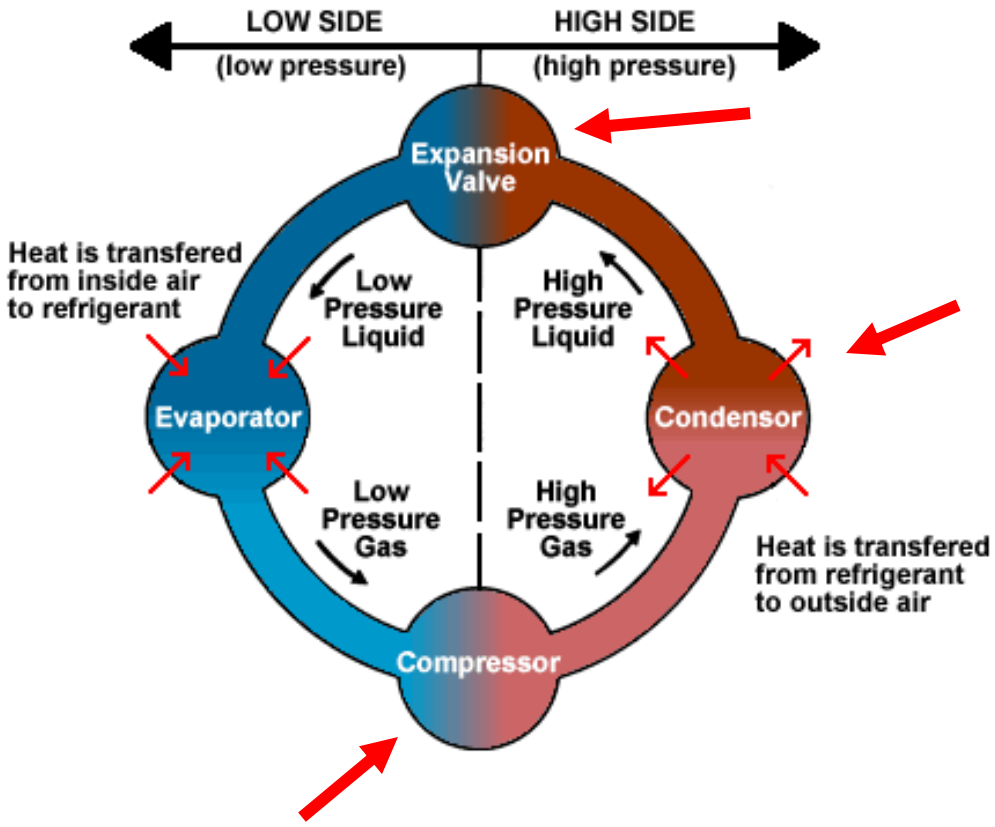
AC Cycle



- Compressor
  - Low-pressure gas compressed to high-pressure gas
- Condenser
  - Hot gas releases heat to outside air
  - Phase change: gas to liquid
- Metering device
  - Restricts flow of high-pressure liquid
  - Pressure drops through expansion valve



www.swtc.edu/Ag_Power/air_conditioning/lecture/basic_cycle.htm

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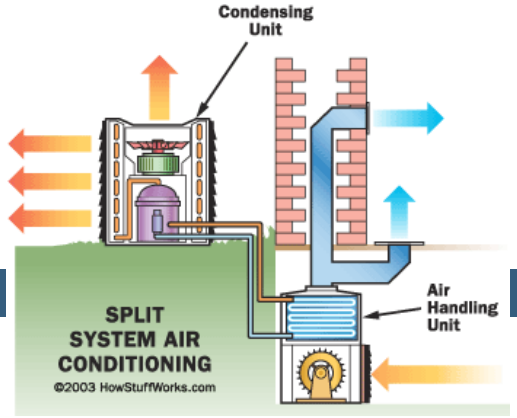
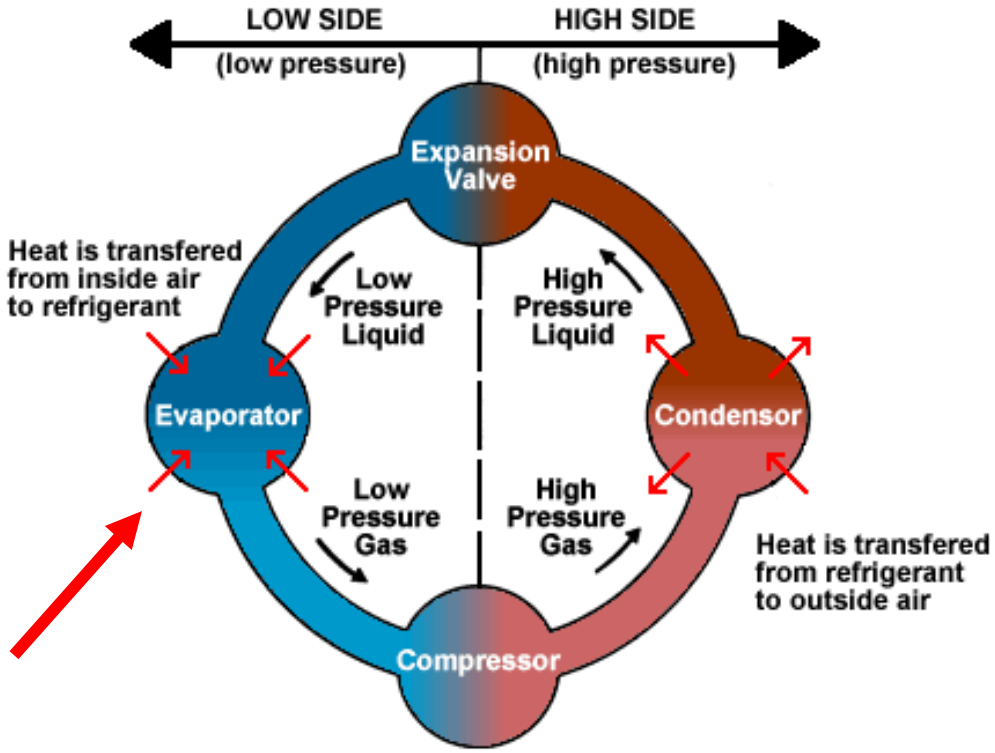
AC Cycle



- Evaporator
  - Liquid absorbs heat from indoor air
  - Phase change: liquid to gas
- Cycle repeats
- Four-part cycle has “high side” and “low side”



www.swtc.edu/Ag_Power/air_conditioning/lecture/basic_cycle.htm

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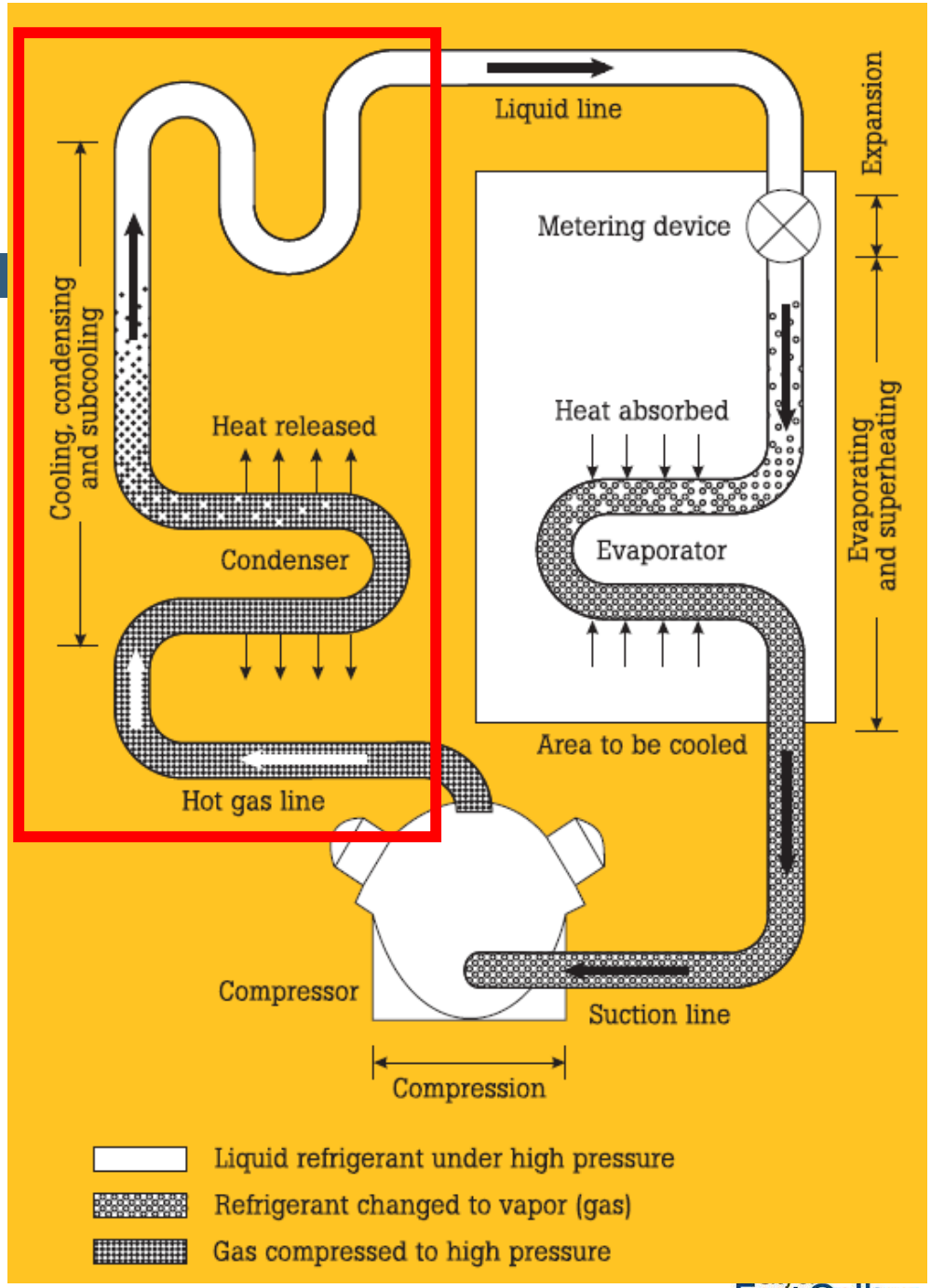
Subcooling

- Compressor elevates refrigerant vapor pressure to higher boiling point
- Boiling point higher than outdoor air temperature
- Air across condensor causes refrigerant to condense
- Additional passes in condenser coil cool liquid refrigerant below its boiling point, to ensure 100% liquid at metering device
- Subcooling = amount of refrigerant temperature drop below boiling point



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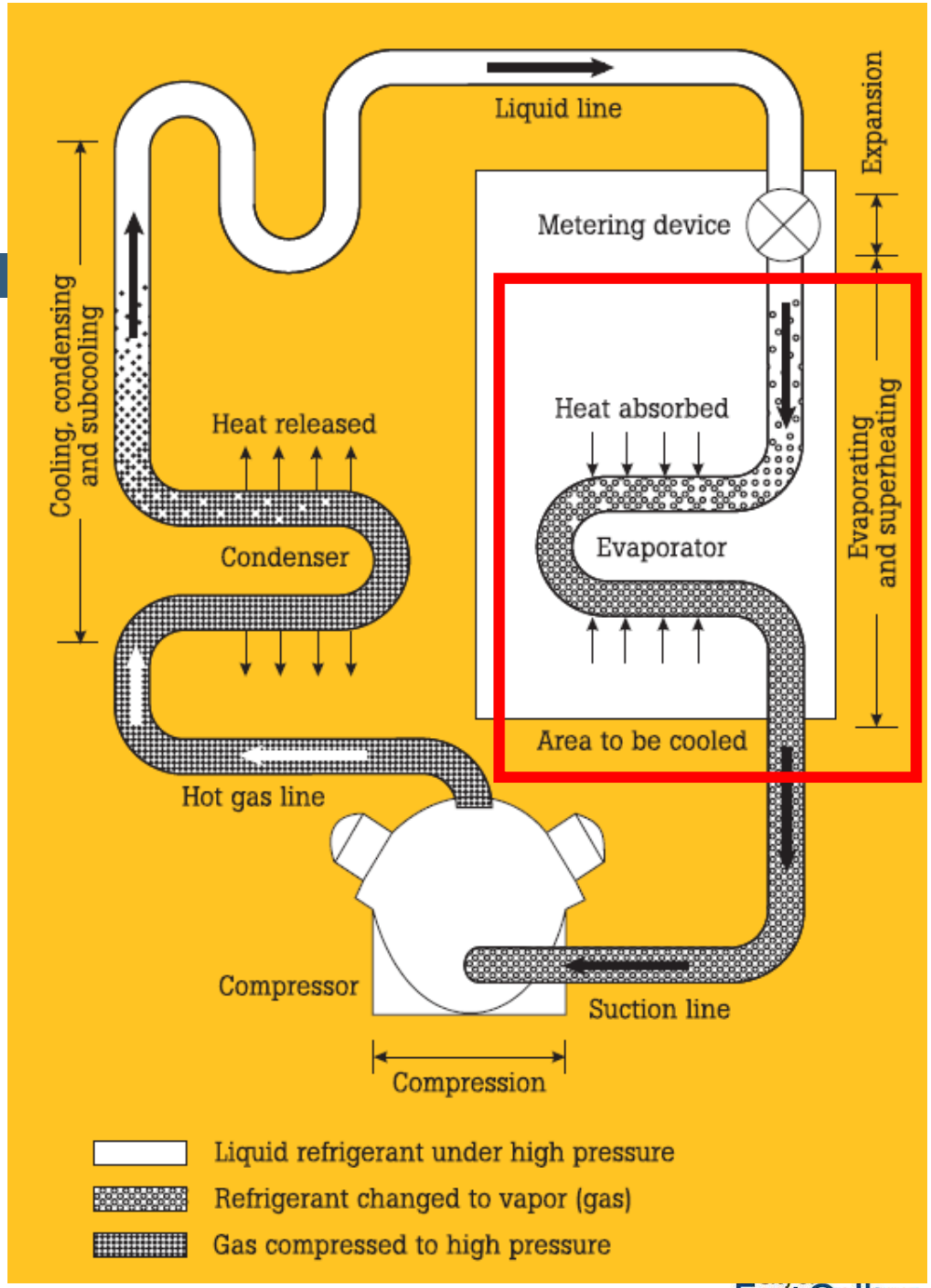
Superheat

- Metering device restricts refrigerant flow, drops refrigerant pressure to new, lower boiling point
- Boiling point lower than indoor air temperature
- Air across evaporator causes refrigerant to boil
- Additional passes in evaporator coil warm gas above its boiling point → ensures 100% gas at compressor
- Superheat = amount of refrigerant temperature rise above boiling point



Fort Collins

REFRIGERANT CHARGE TESTING

Meet at the Condensing Unit

7. Room Airflow + Pressure Balance

Room Airflow

Pressure Balance

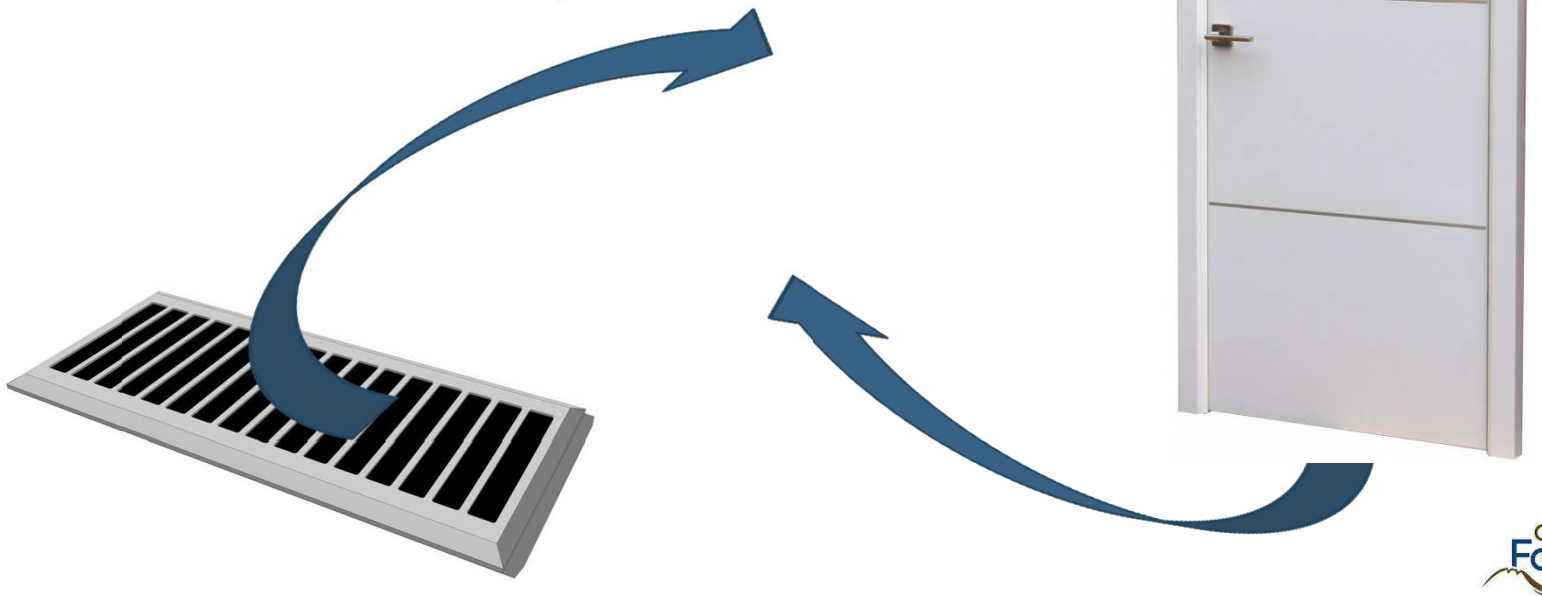
City of Fort Collins

2009 IRC/IMC + Fort Collins Amendments

IRC M1309 Testing and verification

Does it work?

- Supply airflows to each room versus design – not initially enforced
- Pressure balance – easy measurement



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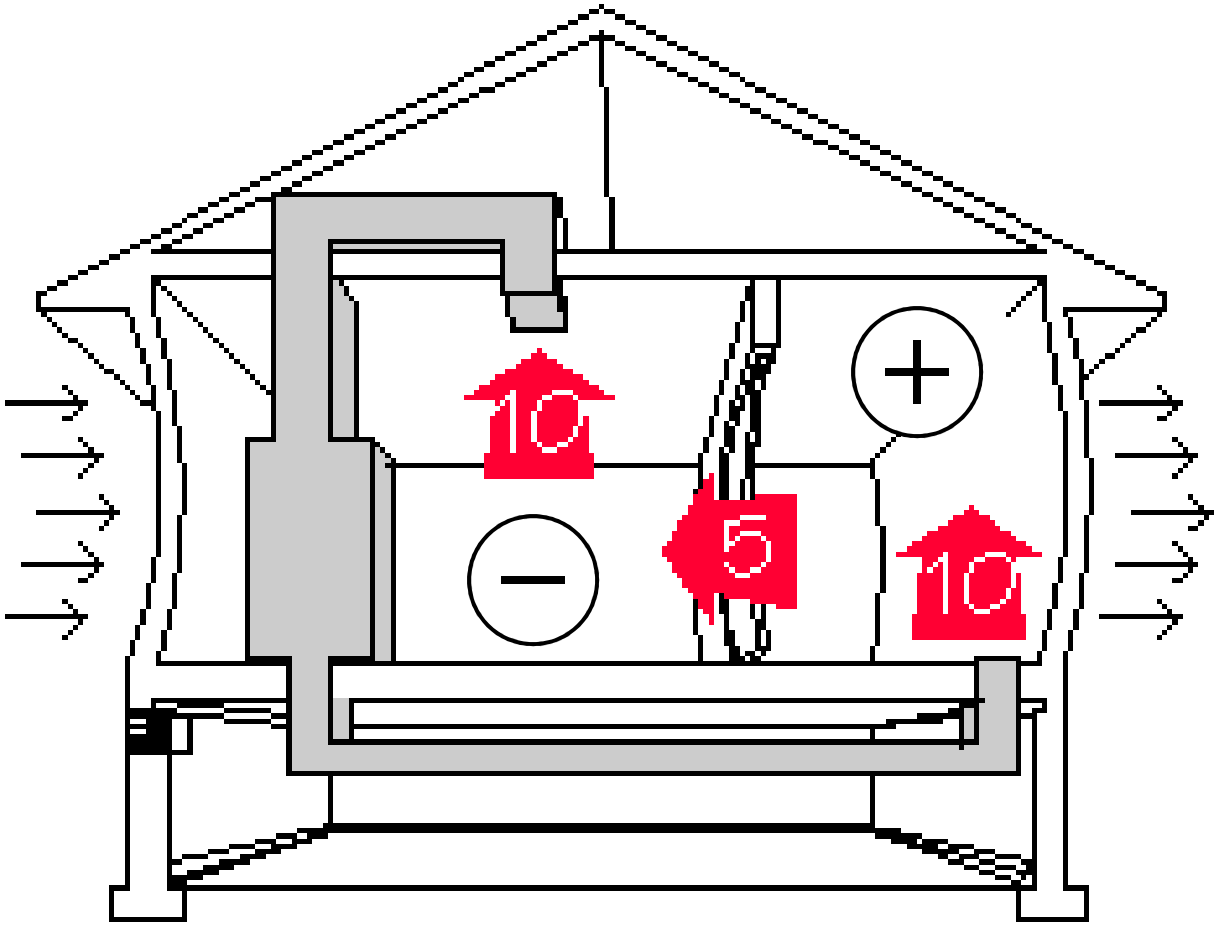
Room Pressure Balance



Insufficient pressure relief

Pressure Imbalance Impacts

- Increase exfiltration / infiltration
- Push moist air into building assemblies
- Pull soil gases into house
- Backdraft natural-draft appliances
- Reduce supply and return flows
- Reduce comfort
- Ghost streaking on carpet

City of Fort Collins

Room Pressure Balance

Setup

- All registers fully open
- All exhaust fans off
- Close all interior doors
- Air handler blower on cooling speed
    - Remember possible need to open circuit breaker to AC outside unit

City of Fort Collins

Room Pressure Balance

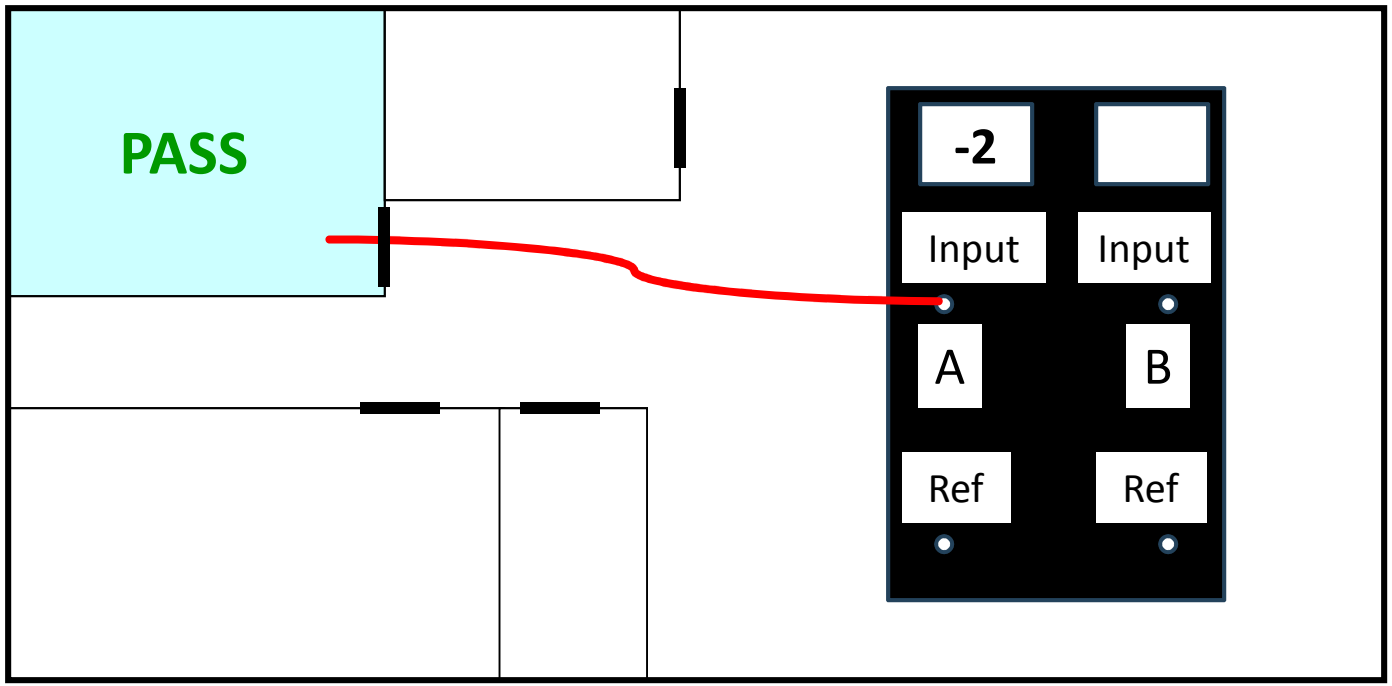
Test

- All rooms where doors can isolate supply register from *core* of house, except where pressure relief not required
  - Bathrooms
  - Laundry room without gas stubbed for dryer (always best practice to provide pressure relief)
- Manometer in core, tube under door

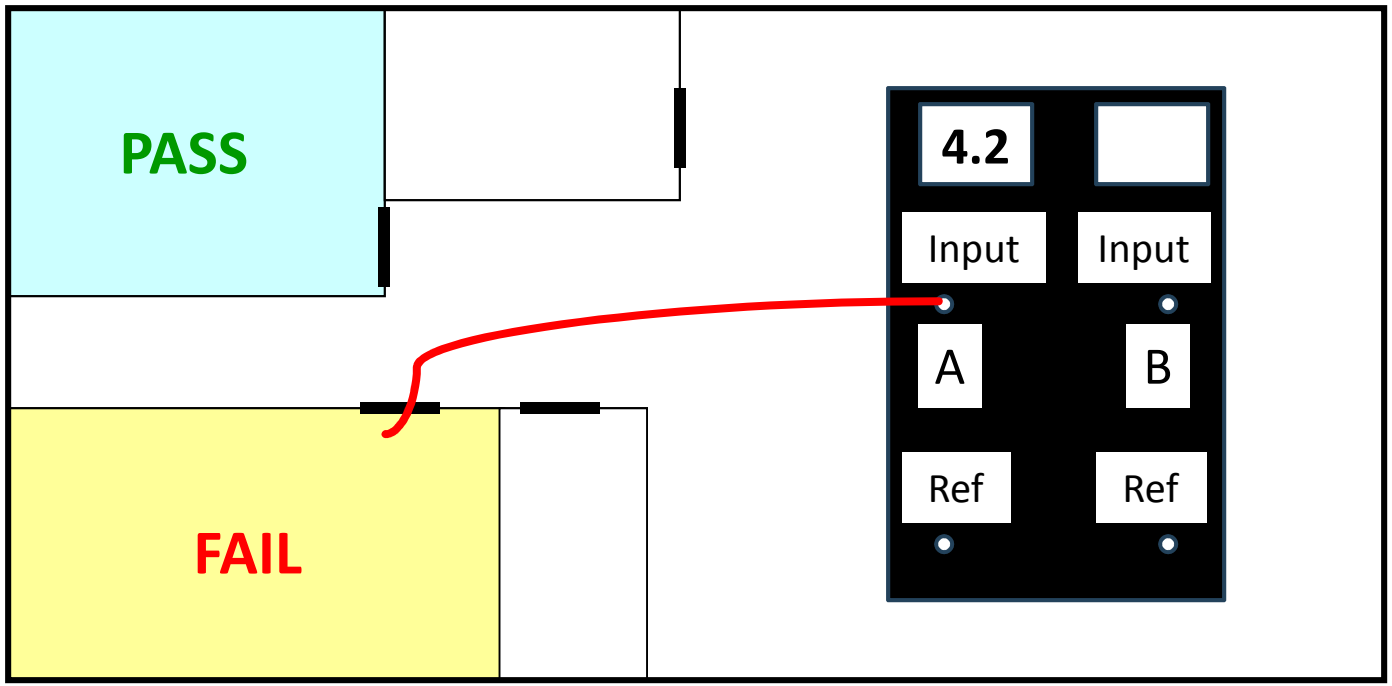
Pass = Room pressure wrt *core* = -3 to +3 Pa

City of Fort Collins

Room Pressure Balance



Room Pressure Balance



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DEMONSTRATE PRESSURE BALANCE MEASUREMENT

Meet in Living Room

8. Combustion Appliance Safety

- Code Requirements – New Homes
- Isolated Mechanical Room
- Combustion Safety Test
- Code Requirements – Existing Homes

City of Fort Collins

2012 IRC/IFGC + Fort Collins Amendment

IRC G2406.2 Prohibited Locations

For <u>new buildings and new appliances within additions</u>

- Natural draft appliances shall not be located within the building thermal envelope . . .

Exception

- Where natural draft appliances are located in an <u>enclosed mechanical room</u> and <u>sealed to air flow</u> from adjoining conditioned area . . .

City of Fort Collins

2012 IRC/IFGC + Fort Collins Amendment

IRC G2406.2 Prohibited Locations

. . . sealed to air flow from adjoining conditioned area and the following conditions are met:

- Self-closing, gasketed door
- Outside combustion air
- No other exhaust appliances in mechanical room
- Verify isolation from house with differential-pressure test
- Natural-draft appliances pass a combustion safety test
- Documentation of satisfactory testing results submitted to building official.

Does it work?

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Mechanical Room Isolation

Does it work?

More difficult than it appears

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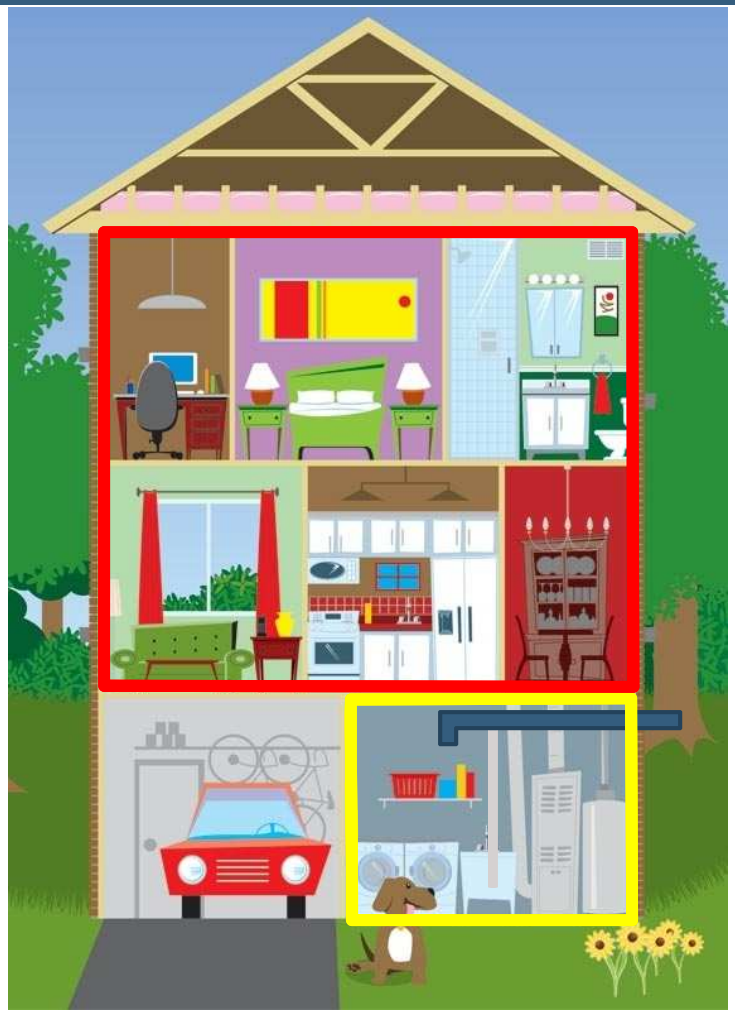
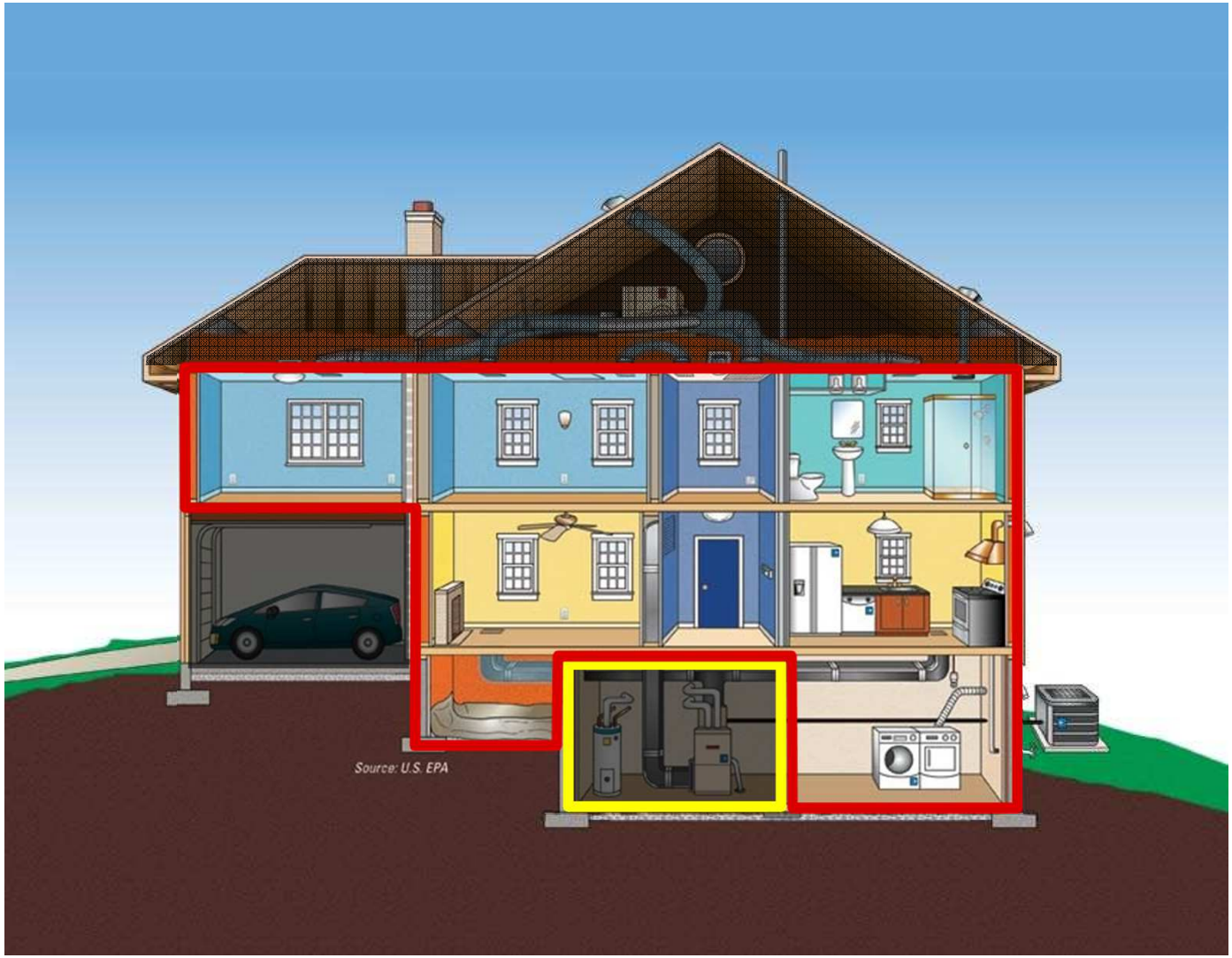
Mechanical Room Isolation

Inside or outside?



Where is the Pressure Boundary?



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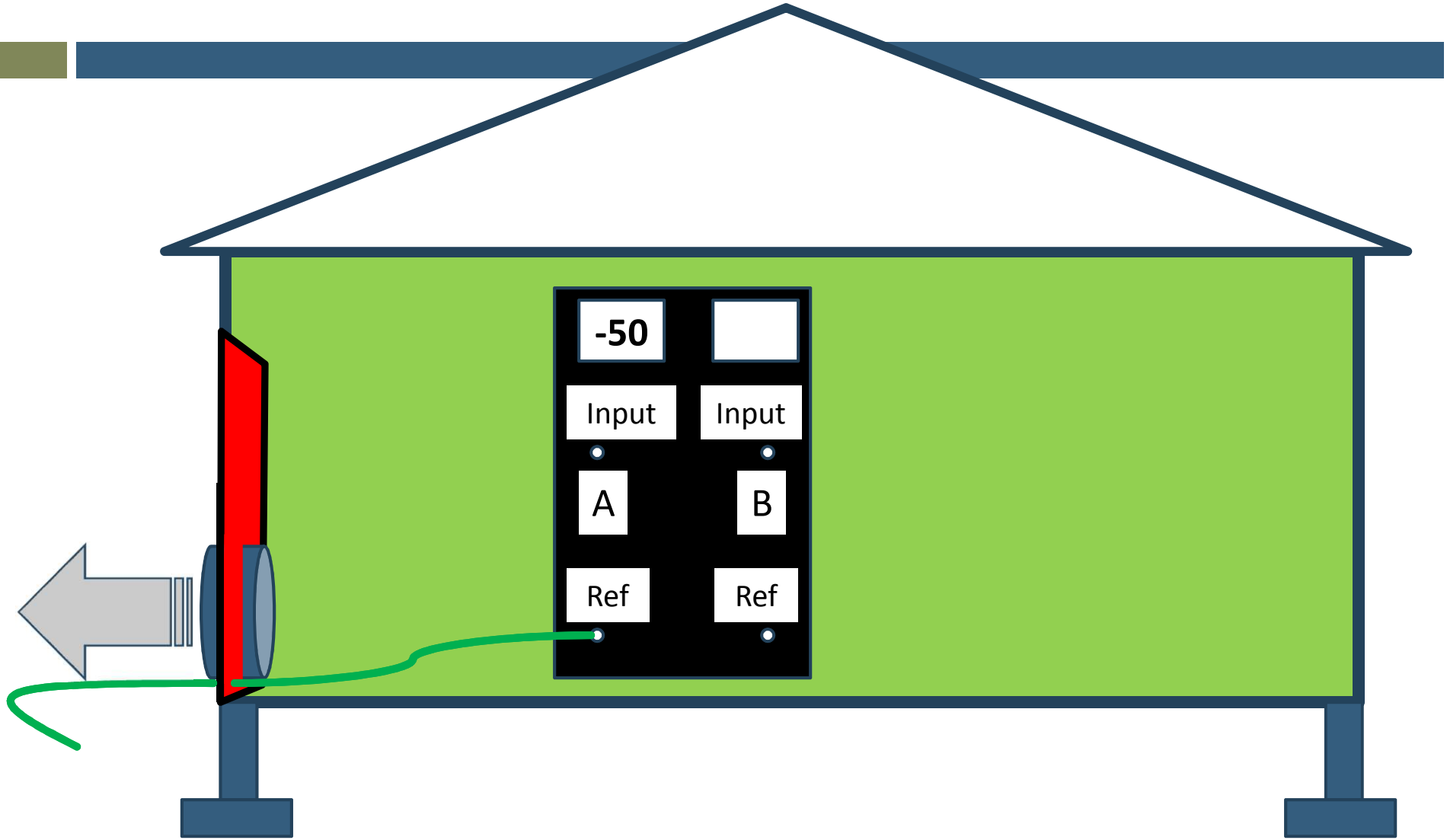
Pressure Differential Test



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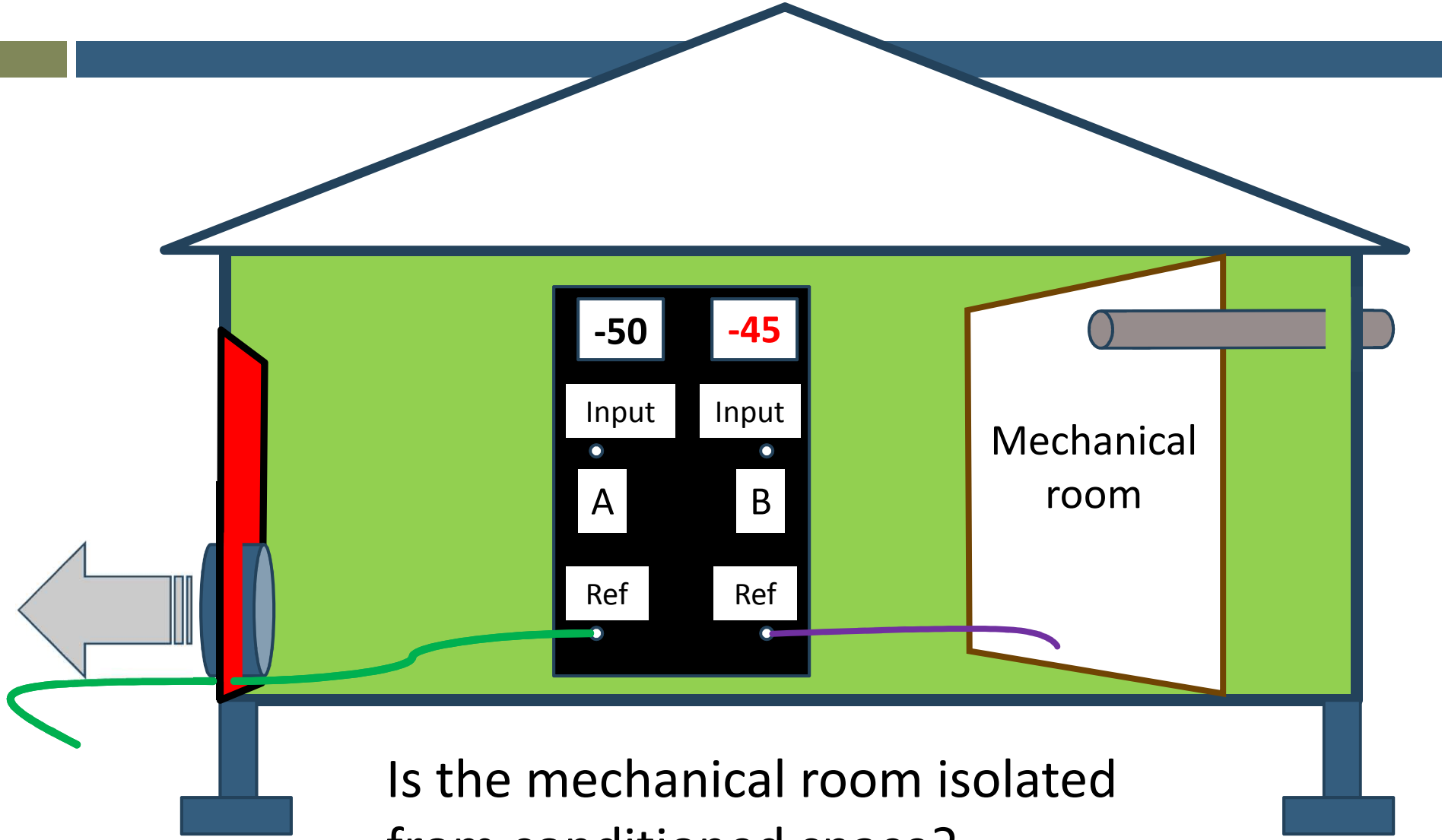
Pressure Differential Test



Is the mechanical room isolated from conditioned space?

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Combustion Safety Test

- Combustion air zone (CAZ) pressure with house in worst case configuration
- Worst case depressurization testing
  - Spillage
  - Draft
  - Carbon monoxide production

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Combustion Appliance Zone (CAZ)

- Zone(s) where combustion appliances are located
- Where is the CAZ boundary?
  - This house?
  - Finished basement?

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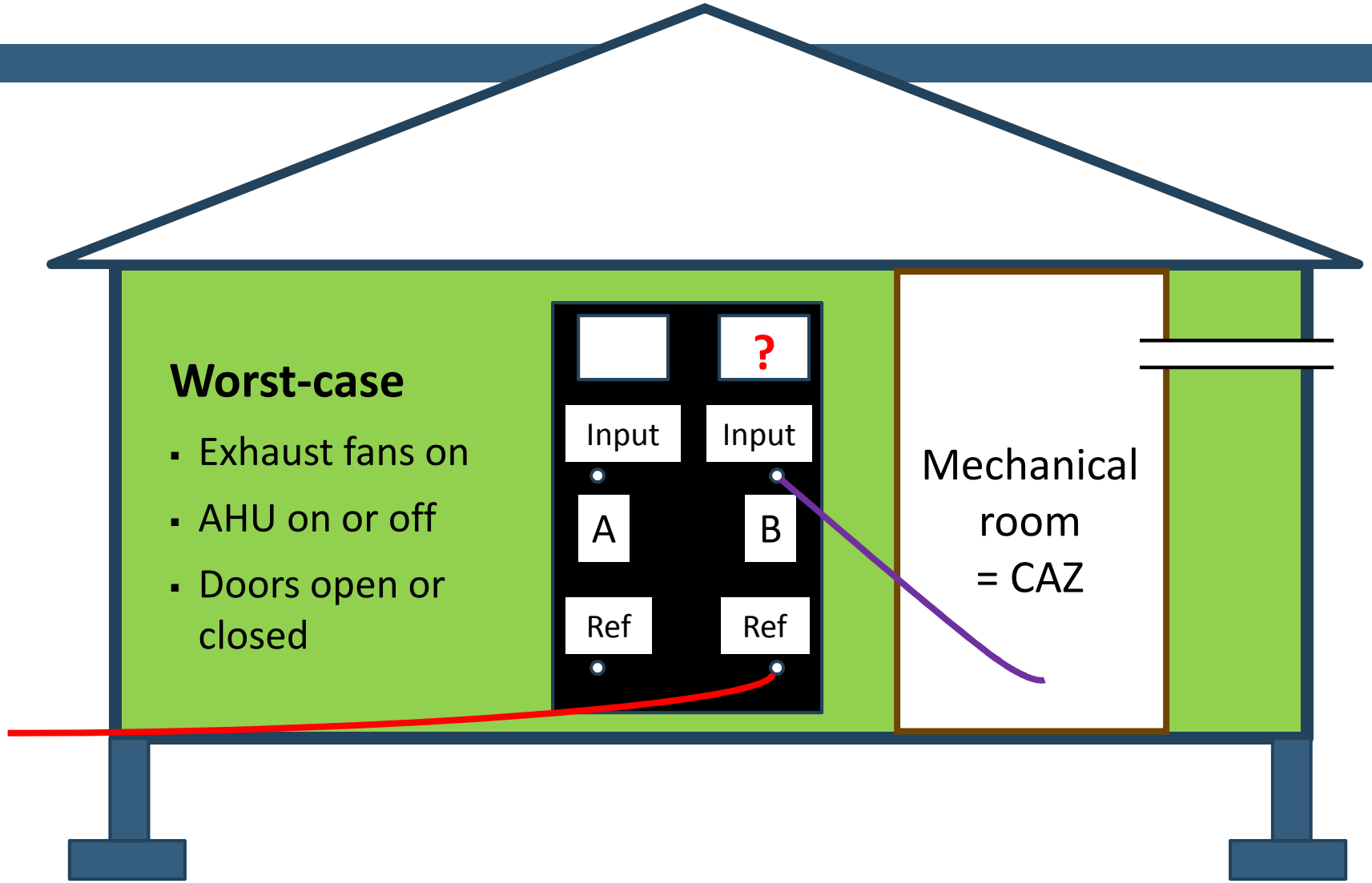
CAZ Depressurization



CAZ Depressurization

CAZ Depressurization Limits

Venting Condition	Limit (Pascals)
Orphan natural draft water heater (including outside chimneys)	-2
Natural draft boiler or furnace commonly vented with water heater	-3
Natural draft boiler or furnace ...nted with water heater	-5
Individual natural draft boiler ...	-5
Mechanically assisted draft bo... with water heater	-5
Mechanically assisted draft boiler or furnace alone, or fan assisted DHW alone	-15
Exhausto chimney-top draft inducer (fan at chimney top); High static pressure flame retention head oil burner; Sealed combustion appliances;	-50

Typical range of concern starts at -3 Pa to -5 Pa

City of Fort Collins

Spillage

Spillage duration after initial fire:

Pass = 0 to 1 minute

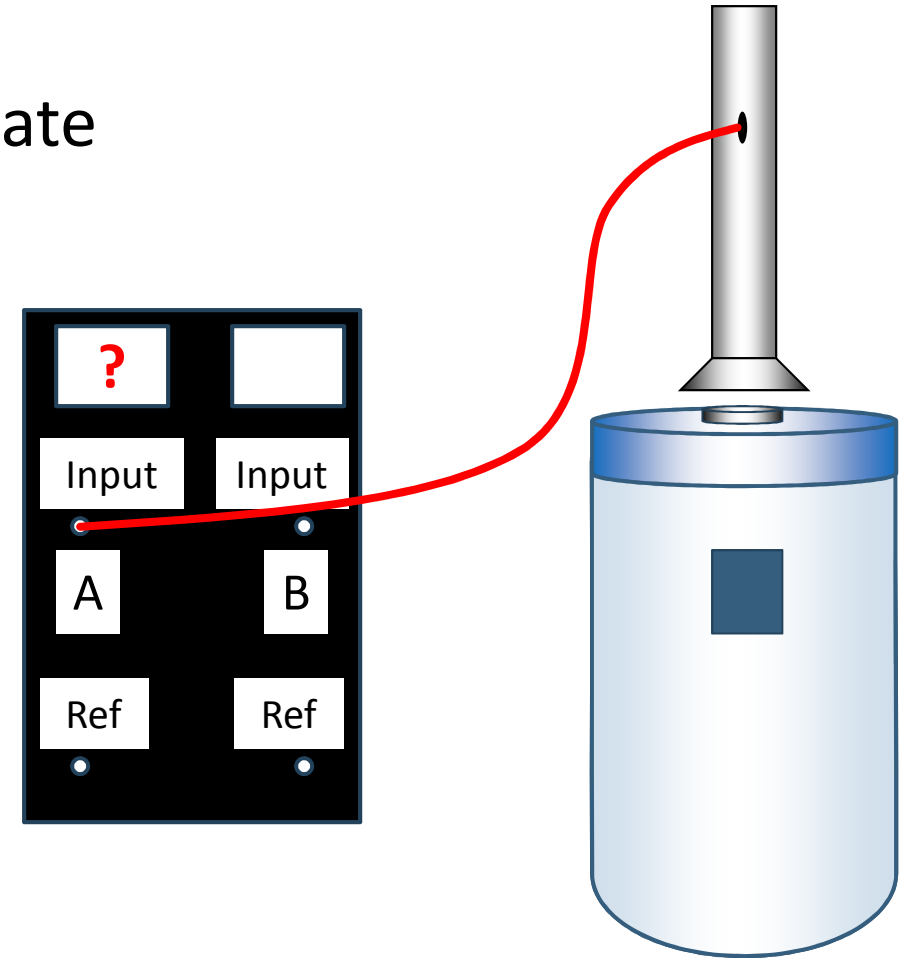
Fail = > 1 minutes

Check with smoke, mirror

Draft

Flue pressure wrt CAZ

- Test draft at steady state
- Negative: flue is drafting
- Positive: backdrafting



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Draft

Target draft varies with indoor-to-outdoor temp difference

Acceptable Draft Test Ranges

Outside Temperature (degree F)	Minimum Draft Pressure Standard (Pa)
<10	-2.5
10-90	(T_out ÷ 40) – 2.75
>90	-0.5

Example:

Outside temperature = 50 F

Minimum draft pressure = (50 / 40) – 2.75

Draft pressure must be -1.5 Pa or more negative

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Carbon Monoxide

- Zero CO meter with outdoor air
- Sample undiluted flue gas
- Water heater at steady state (5 to 10 minutes)

New home limits:

Pass = 0 - 100 ppm air free

Fail = > 100 ppm air free

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2012 IRC/IFGC + Fort Collins Amendment

IRC G2408.1 Equipment replacement in existing homes

Where natural draft appliances are replaced in existing buildings, all appliances with a draft hood . . .

- Must pass combustion safety test under natural conditions
- Also tested under worst-case conditions; if fails, homeowner disclosure form required

City of Fort Collins

Carbon Monoxide

Combustion Safety Test Action Levels

CO Test Result*	And/ Or	Spillage and Draft Test Results	Retrofit Action	
0 – 25 ppm	*And*	Passes	Proceed with work	Pass
26 – 100 ppm	*And*	Passes	Recommend that the CO problem be fixed	Pass
26 – 100 ppm	*And*	Fails at worst case only	Recommend a service call for the appliance and/or repairs to the home to correct the problem	HO disclosure
100 - 400 ppm	*Or*	Fails under natural conditions	Stop Work: Work may not proceed until the system is serviced and the problem is corrected	Fail
> 400 ppm	*And*	Passes	Stop Work: Work may not proceed until the system is serviced and the problem is corrected	Fail
> 400 ppm	*And*	Fails under any condition	Emergency: Shut off fuel to the appliance and have the homeowner to call for service immediately	Fail

**CO measurements for undiluted flue gases at steady state*

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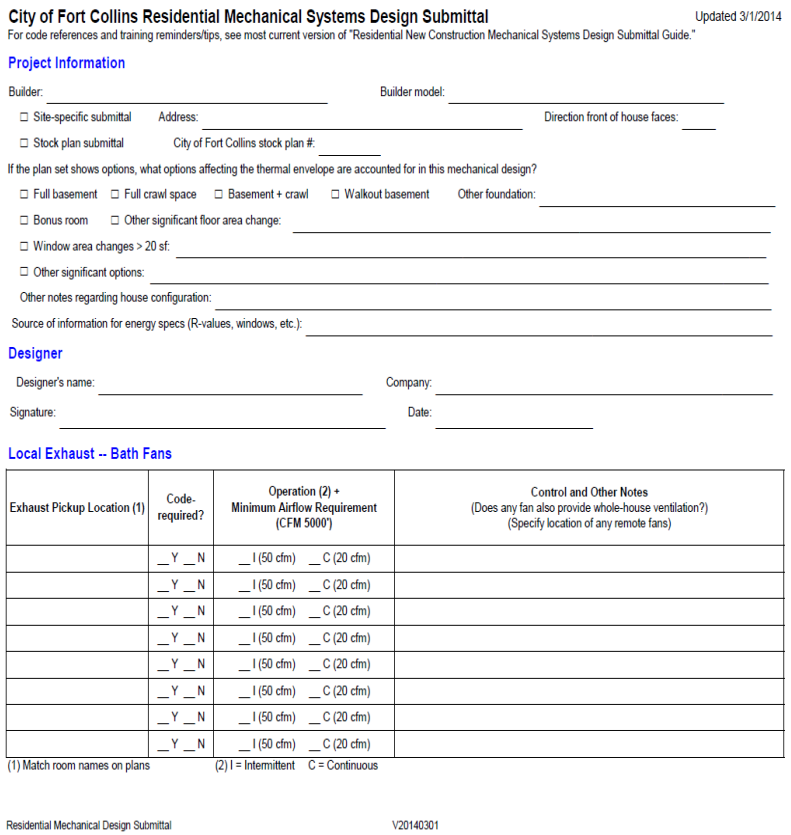
9. System Controls

- Do all fans, whole house ventilation, sub-structural floor exhaust, heating, and cooling systems controls operate the per design submittal ?



City of Fort Collins Residential Mechanical Systems Design Submittal Updated 3/1/2014

For code references and training reminders/tips, see most current version of "Residential New Construction Mechanical Systems Design Submittal Guide."

Project Information

Builder: _____ Builder model: _____

☐ Site-specific submittal Address: _____ Direction front of house faces: ____

☐ Stock plan submittal City of Fort Collins stock plan #: _____

If the plan set shows options, what options affecting the thermal envelope are accounted for in this mechanical design?

☐ Full basement ☐ Full crawl space ☐ Basement + crawl ☐ Walkout basement Other foundation: _____

☐ Bonus room ☐ Other significant floor area change: _____

☐ Window area changes > 20 sf: _____

☐ Other significant options: _____

Other notes regarding house configuration: _____

Source of information for energy specs (R-values, windows, etc.): _____

Designer

Designer's name: _____ Company: _____

Signature: _____ Date: _____

Local Exhaust -- Bath Fans

Exhaust Pickup Location (1)	Code-required?	Operation (2) + Minimum Airflow Requirement (CFM 5000')	Control and Other Notes (Does any fan also provide whole-house ventilation?) (Specify location of any remote fans)
	__Y __N	__I (50 cfm) __C (20 cfm)	
	__Y __N	__I (50 cfm) __C (20 cfm)	
	__Y __N	__I (50 cfm) __C (20 cfm)	
	__Y __N	__I (50 cfm) __C (20 cfm)	
	__Y __N	__I (50 cfm) __C (20 cfm)	
	__Y __N	__I (50 cfm) __C (20 cfm)	
	__Y __N	__I (50 cfm) __C (20 cfm)	
	__Y __N	__I (50 cfm) __C (20 cfm)	

(1) Match room names on plans (2) I = Intermittent C = Continuous

Residential Mechanical Design Submittal V20140301 Page 1

CONGRATULATIONS!

YOU'VE DEVELOPED A HIGHER LEVEL OF PERFORMANCE TESTING PROFICIENCY!

Performance Testing Credential

Once you begin performance testing…

- City: Random spot-checking of your forms (QC)
- You: maintain proficiency by keeping quality consistently high (Hint: develop and implement your own QA program)
  - Minor issues will be addressed with discussion or mentoring from City of Fort Collins and/or Group 14
  - Repeat major problems: Delays in issuance of C.O.

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Contact Info

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- Nick Buike, Group 14 Engineering

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