HVAC Air Duct Leakage

November 2013

Presented By:
Mark Terzigni
Project Manager
Technical Services
SMACNA

Learning Objectives

- Understand the difference between "System" leakage and "Duct" leakage
- Understand what information is required to properly specify duct leakage tests
- Understand what various codes and standards require for duct air leakage testing
- Understand misconceptions related to duct leakage testing

The New Leakage Manual

- SMACNA has completed the second edition of the HVAC Air Duct Leakage Test Manual
- First chapter devoted to designers and specifiers
- “Tightened up” the leakage classes
- Completed the ANSI process

What is “Duct Leakage”

- Duct leakage is the leakage of air from **DUCT**
- Equipment leakage is the leakage of air from **EQUIPMENT**
- Accessory leakage is the leakage of air from **ACCESSORIES**

System Leakage

- HVAC Air System Leakage is the **combination** of duct, equipment and accessory leakage.

- **DUCT leakage is not SYSTEM leakage**

Is Testing Justified?

- Many people agree that testing at least a portion of the ductwork is justified.
- How much should you test?
- What sections of duct should you test?

How much to test?

- The majority of energy codes/standards require 25% of the “high-pressure” duct to be tested…

- **ASHRAE 90.1 2010**:
  - **6.4.4.2.2** Duct Leakage Tests. Ductwork that is designed to operate at static pressures in excess of 3 in. w.c. and **all ductwork located outdoors** shall be leak-tested according to industry-accepted test procedures (see Informative Appendix E). Representative sections totaling **no less than 25%** of the total installed duct area for the designated pressure class shall be tested. All sections shall be selected by the building owner or the designated representative of the building owner. Positive pressure leakage testing is acceptable for negative pressure ductwork.

How much to test?

- **IECC 2012**:
  - **503.2.7.1.3** High-pressure duct systems. …shall be leak tested in accordance with the SMACNA *HVAC Air Duct Leakage Test Manual…* Documentation shall be furnished by the designer demonstrating that representative sections totaling **at least 25 percent** of the duct area have been tested…

How much to test?

- **IGCC V2**

607.4.1 Duct Air Leakage Testing. Ductwork that is designed to operate at static pressures exceeding 3 inches water column and all ductwork located outdoors shall be leak-tested in accordance with the SMACNA *HVAC Air Duct Leakage Test Manual.* Representative sections totaling **not less than 25%** of the total installed duct area for the designated pressure class shall be tested.

How much to test?

- Some believe that 100% testing is required, and it is the only way "to be sure"…

- Perhaps a more practical approach is the 25-50-100 approach…

What about “low-pressure” duct?

- This is where discretion must be used.

- “…low pressure duct leaks more than high pressure duct…”
  - This statement is true if the duct is tested at the same pressure, especially in older buildings where the seal class varied by pressure class.

What about “low-pressure” duct?

- As seal class “A” becomes the norm the difference in leakage (at the same pressure) will likely decrease or perhaps disappear altogether. So under operating conditions the potential leakage for the low pressure side would be lower because the operating pressure would be lower

What about "low-pressure" duct?

- Leakage is also a function of the "size of the hole" which means it is a function of the amount of duct used.
- If the majority of duct is low pressure it may be justified to test some of it.
- USE 25-50-100 (10-20-100)

Code Update

- IAPMO Green Plumbing and Mechanical Code Supplement
- Duct Leakage Tests. Ductwork ~~that is designed to operate at static pressures in excess of 3 inches Water Column~~ (0.75 kPa) and all ductwork located outdoors shall be leak-tested according to the ANSI/SMACNA HVAC Air Duct Leakage Test Manual. Representative sections totaling no less than ~~25~~ 20% percent of the total installed duct area ~~for that designated pressure class~~ shall be tested. Should the tested 20% fail to meet the requirements of this section, then 40% of the total installed duct area shall be tested. Should the tested 40% fail to meet the requirements of this section, then 100% of the total installed duct area shall be tested. All sections shall be selected by the building owner or the designated representative of the building owner. Positive pressure leakage testing is acceptable for negative pressure ductwork. The maximum permitted duct leakage shall be:

Why not use a % to fan flow?

- Leakage is a function of pressure
- And the "size of the hole"

$$F = C_L P^N$$

Why not use a % to fan flow?

- As mentioned earlier Leakage is a function of pressure, and it is a function of “the size of the hole”
- Leakage is not a function of the volume of air

Why not use a % to fan flow?

- ASHRAE RP 1292

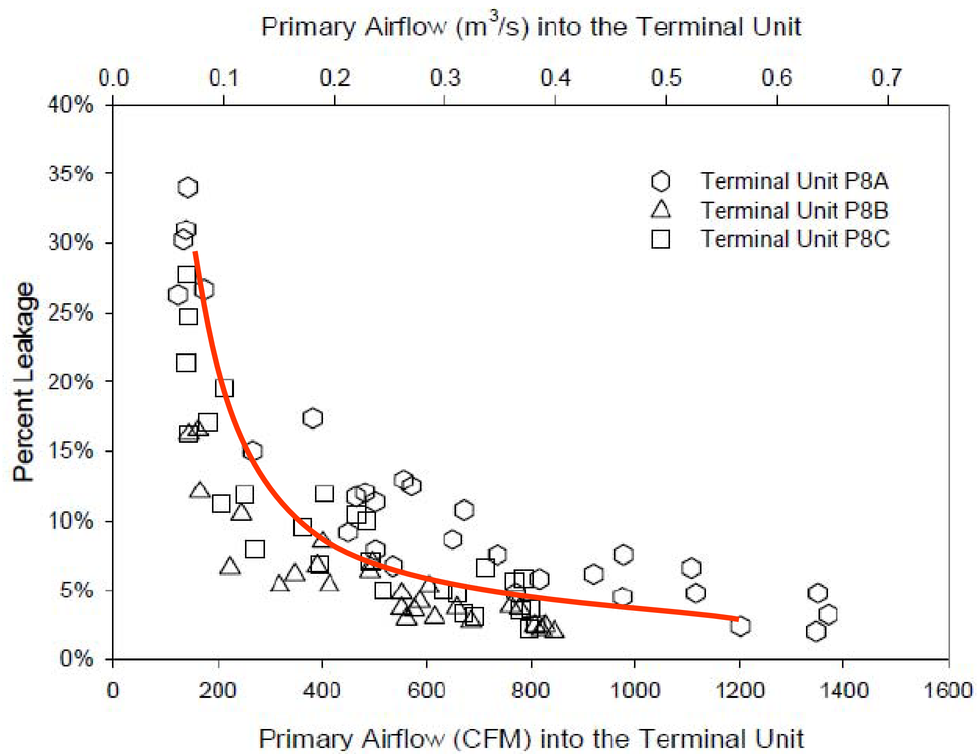


Figure 5-10 – Percentage Air leakage for three 8 inch parallel terminal units.

Why not use a % to fan flow?

Figure 5-10 shows a plot of the **percentage leakage as a function of the supply airflow** from the eight inch terminal units. **In general, the percent of leakage (Qleakage divided by Qprimary) increased as the primary airflow decreased**.

Why not use a % to fan flow?

- Put simply as the “fan flow” decreased the percentage of leakage increased…

- This is likely because the leakage itself stayed nearly constant because the test pressure was the same.

Why not use a % to fan flow?

- ALL of the codes/standards mentioned earlier use a leakage class for duct, not a percent.
- 90.1-2010 class 4 all duct
- IECC class 3 round / class 6 rectangular
  - UPDTAE Class 4 all duct
- IGCC class 4 all duct
- IAPMO GPMCS class 4 all duct

Where should a % be used?

- The percent to fan flow should be used during the <u>**design**</u> process.

- The summation of duct, equipment, and accessory leakage can be limited to X% of fan flow.
- This is a function of design/spec/fab/install

“CHAIN of RESPONSIBILITY”

- The first link in the chain is the DESIGNER
  - How a system performs is dependent on how it was designed
- MANUFACTURERS
  - They must provide equipment that performs as “advertised”
- FABRICATOR/INSTALLERS/CONTRACTORS
  - They must fabricate and install items correctly
- Code Bodies
  - Must enforce codes consistently and correctly

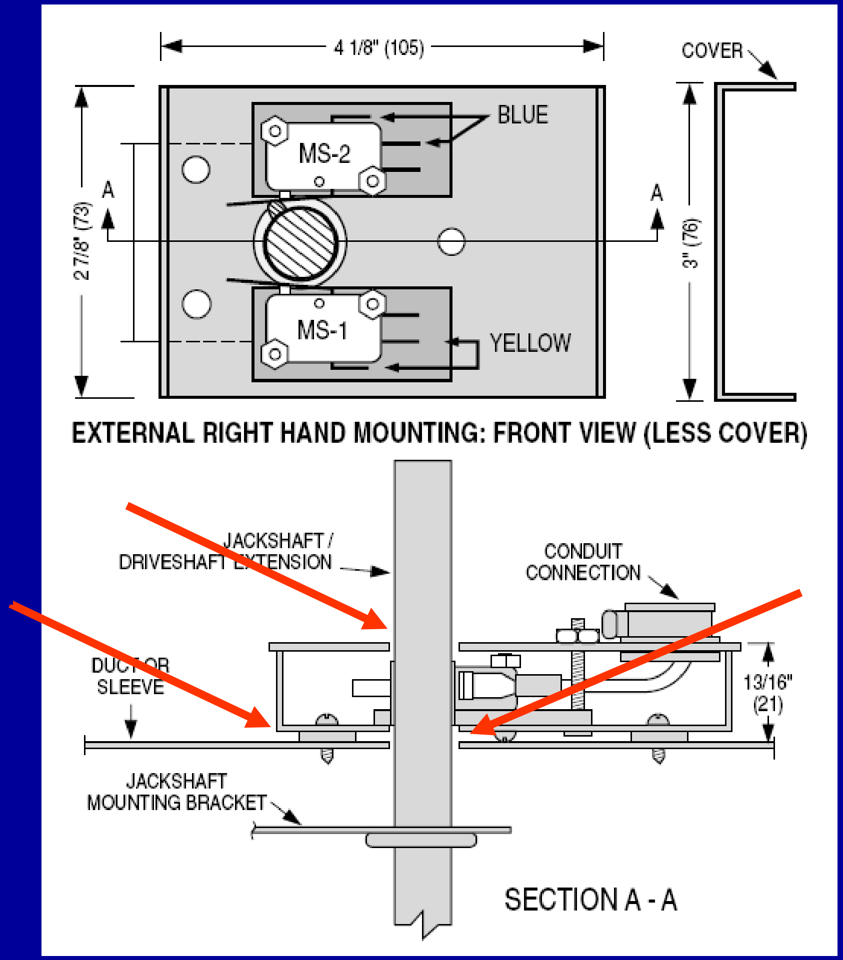
Real Issue to Avoid

- When arbitrary requirements for pass/fail are used and are also misapplied the contractor is forced to decide what to comply with.

- What happens when a spec differs from codes/standards/warranties/listings (UL)?

Control Rod for Fire Damper

Do NOT apply sealant at these locations



Quote from Manufacturer

"It is extremely important to **specify** and **order** the correct product. **Field** repairs or **modifications almost always result in a loss of UL certification**. If repairs or modifications are required, the AHJ must be consulted."

Where can we get info on equipment or accessories?

- The industry currently has several sources for designers to use to get info on leakage for equipment and accessories. There are still gaps, and the industry is working to close them.

Equipment Leakage Test

- ASHRAE Standard 193 authorized September 30, 2006.
  Method of Testing for Determining the Air-Leakage Rate of HVAC Equipment
- Published mid-summer 2010.
- 1. PURPOSE:
  - This standard prescribes a method of testing to determine the air-leakage rate of forced-air heating, and cooling HVAC equipment, prior to field installation.

SMACNA

Equipment Leakage Test

- 2. SCOPE:
  - 2.1 This standard applies to the following:
    a) Equipment intended for installation in ducted systems, including furnaces, heat pumps, air conditioners, coil boxes, filter boxes, and associated components.
    b) Equipment that moves less than 3000 cfm (1400 L/S) of air.
  - 2.2 It does not apply to field installed components, such as plenums or ducts.
  - NOTE no PASS/FAIL criteria and <u>does not apply to VAV boxes</u>

SMACNA

Equipment Leakage Data

- ASHRAE RP 1292
- Was not the intent to evaluate leakage
- Turned out that leakage was considerable

- Leakage rates for boxes were 5%-30%...That’s right, the best boxes still hit 5% and those rates are at non-typical operating conditions ie 1200 cfm for and 8 in.box (v~3400 fpm)

Box Leakage

- ASHRAE RP 1292

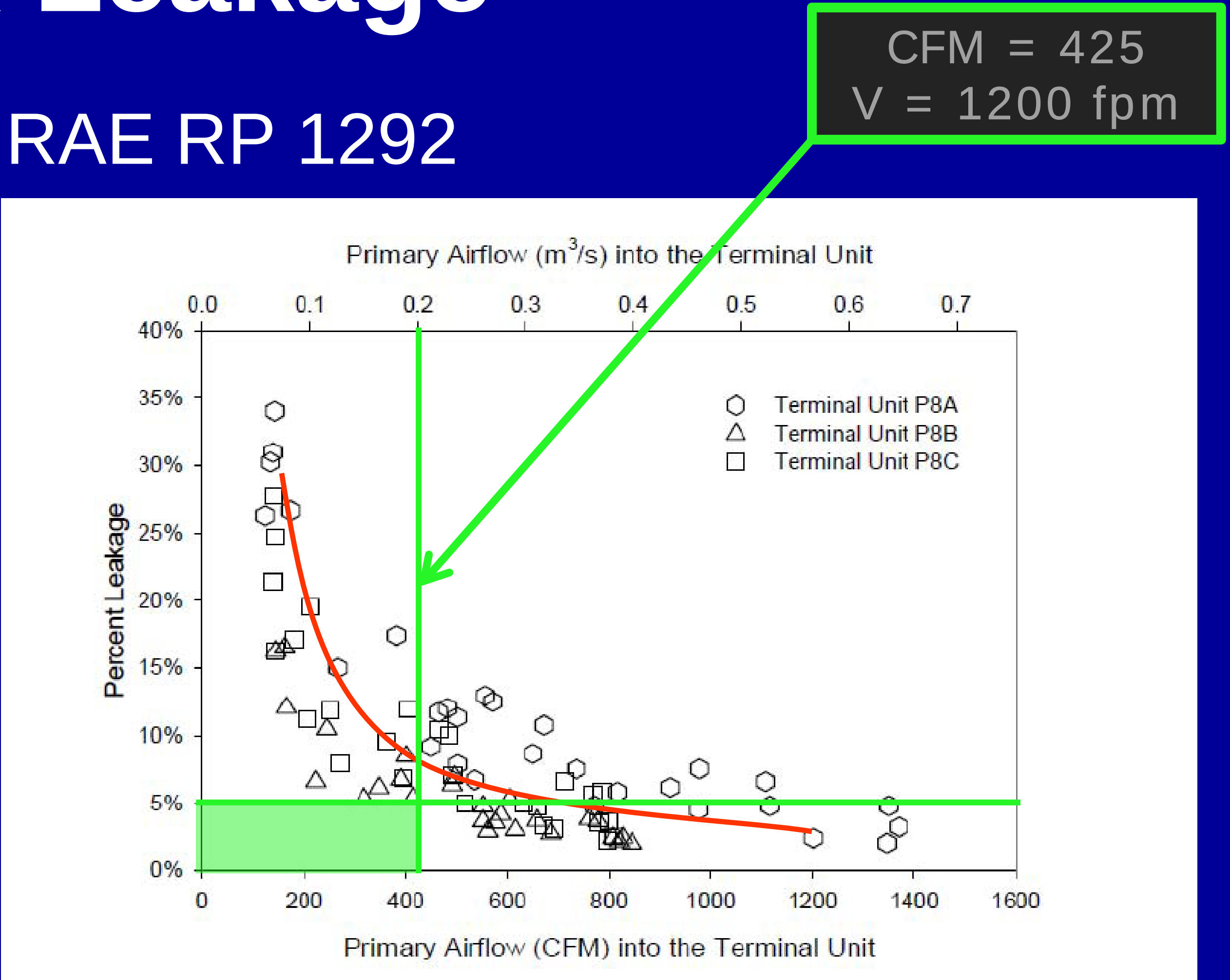


Figure 5-10 – Percentage Air leakage for three 8 inch parallel terminal units.

Misconceptions

- The cost associated with testing the duct system is basically the time and material to perform the test.

- Not true…Often the largest expense associated with testing is the disruption to workflow or job schedule in addition to the time and materials to perform the test.

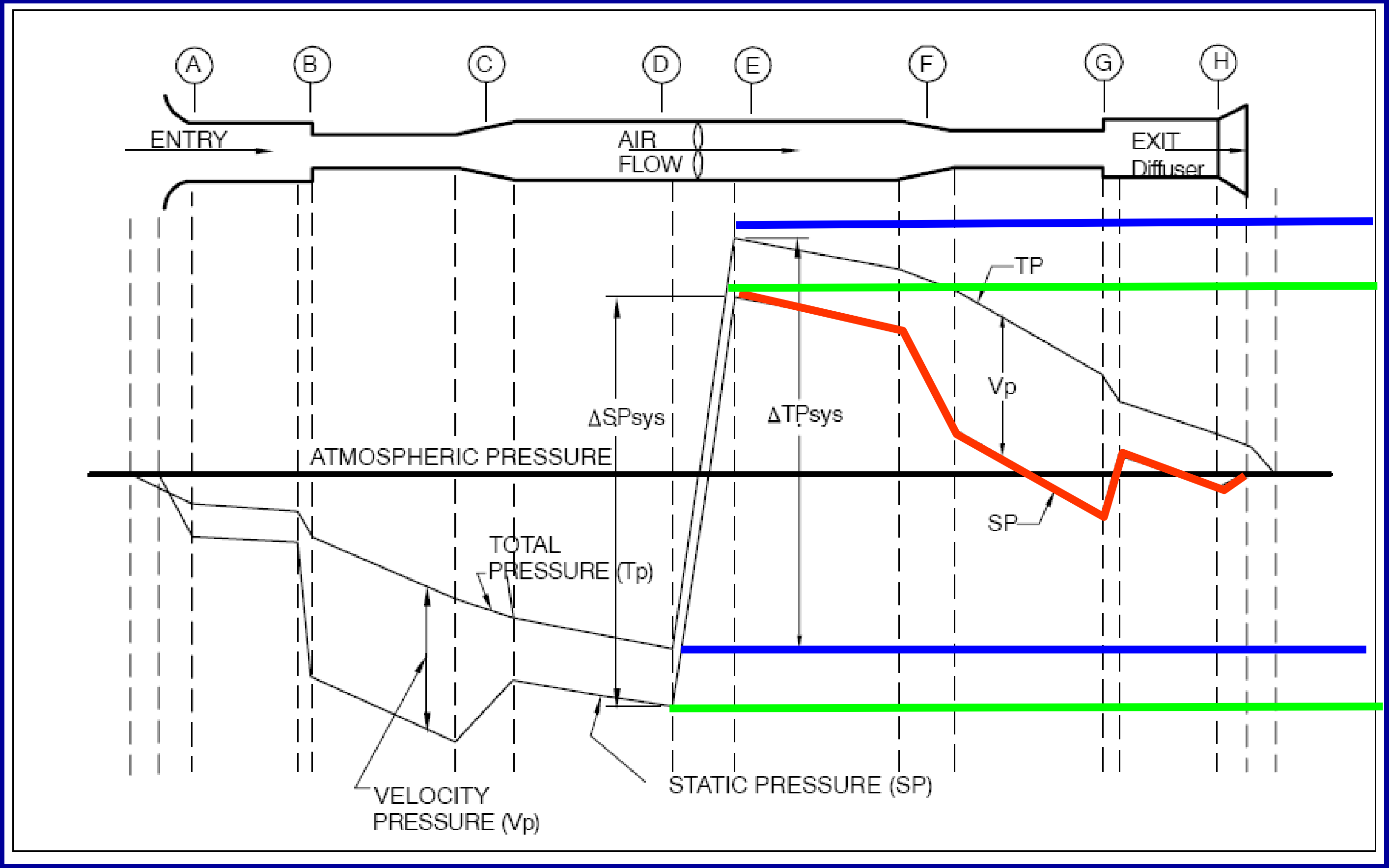
Misconceptions

- The leakage rate determined through testing (SMACNA, ASHRAE) is the actual leakage under operating conditions

  - Test pressures do not typically match operating pressures

  - Also, this test is intended for duct not for the system

Misconceptions



Air Leakage Misconceptions

- Mean pressure:
  - Standards in Europe utilize the concept of mean pressure for duct testing.
    - Example: The “high pressure” portion of a duct system requires 4 in. w.g. at the fan but only 2 in. w.g. at the VAV boxes. The test pressure would be 3 in. w.g. [(4+2)/2 = 3]
  - The goal is to make test conditions closer to operating conditions.

Air Leakage Misconceptions

- Real life example…
  - Down Stream of VAV box
  - Spec's required duct fabricated to 2 in. w.g.
  - Engineer wanted leakage testing done at 4 in. w.g.
  - Engineer wanted testing through flex to diffuser
  - Max 2% leakage allowed (9.2 CFM)
- Typical downstream section
  - 10' o f 12 x 10 rect. Duct 12'of 9" round duct
  - 1 lo-loss tap, and 1 90° elbow
  - 2 outlets (230 CFM each), 5' flex on each

Air Leakage Misconceptions

- Let's assume all leakage is from the rigid duct
  - Total rigid duct surface area 66 ft^2
  - 9.2 CFM/65 ft^2 x 100 = 14 cfm/100 ft^2 = F
  - $C_L = F/P^{0.65} = 14/4^{0.65} = 5.7 \sim 6$
  - Is this attainable? Yes and No…
  - Yes, for the rigid duct in this example an average leakage class of 6 is attainable, but not expected using the code compliant practices at the time.
    - Seal Class A and other construction options can achieve this leakage class, but there is a cost associated with this…

Air Leakage Misconceptions

- What happens if we tested this at 2 in. w.g.?
- Per the first edition of the leakage manual the “average” leakage class for the rigid duct is 19.
- This would permit a pass if the rigid duct leaked 19 CFM or less at 2 in. w.g. S.P.
- Does that mean the rigid duct would leak 4%?
- Yes and No
  - Yes, under these test conditions it would leak about 4%
  - No, this leakage is not the same as leakage under operating conditions.

SMACNA

Air Leakage Misconceptions

- Reality check…
  - Analysis of the system shows that it would operate 0.1 to 0.13 in. w.g.(From VAV to diffuser)
    - Includes rigid duct loss, fitting loss, flex duct loss (@15% compression), and max static pressure for diffusers)
  - Even at a leakage class of 48 (unsealed duct) at the maximum expected operating pressure (.13 in. w.g.) the rigid duct would leak about 8 CFM or 1.8% This is less than the 2% or 9.2 CFM allowed by spec.
  - Remember the mean pressure theory?

Air Leakage Misconceptions

- Reality check…
  - Now, if we use the actual leakage class for the rigid duct (round and rect. combined) CL = 19 @ the expected average operating pressure 0.065 in wg
  - The actual leakage would be closer to 2 CFM or 0.4% leakage under operating conditions.
- What else does this illustrate?
  - Leakage testing for low pressure systems is not a good use of time/money/effort.
  - Looking at actual operating conditions your maximum benefit for this example is 3 CFM (0.65%). That is assuming the duct goes from unsealed to sealed.

Good Practices

- Test some of the ductwork early on in the construction process
  - It will make sure that all parties involved understand what is expected
  - It will identify any potential issues early which makes them easier and less expensive to fix

Good Practices

- Write a good specification
  - Detail how much duct is to be tested
    - 25-50-100
  - Provide a “correct” pass/fail criterion
    - AVOID arbitrary values such as **X**%
    - Use available data from research
  - Specify seal class “A” for duct
  - NEVER SPECIFY TEST PRESSURES GREATER THAN THE CONSTRUCTION CLASS

Summary

- Testing 100% of the ductwork is rarely justified
- Testing ductwork does not reduce leakage
  - Sealing ductwork reduces leakage
- There is no consensus based method of test for an entire system
- There is no consensus based method to determine a correct pass/fail criteria for the system

Updates/News

- What tools are now available ?

- What is the industry working on?
  - New standards
  - Changes to existing standards

IS THERE AN APP FOR THAT?

APPS!!!!

- SMACNA has released an app that calculates duct air leakage.
  - On I-tunes, Droid Market
  - Generates an email report
  - Free!!
  - Web based version available www.smacna.org/dalt

Who?

- **Designers**
  - Account for duct leakage during design
  - Typically use an arbitrary percent which is not consistent with the research, standards, or codes
- **Contractors**
  - Provides an easy way to determine the pass/fail criteria
  - Consistent with standards and codes
- AHJ's and Code officials
  - Provides an easy way to verify compliance
  - Can simply review the report

How do I access the tool?

- The calculator is available for free at:

www.smacna.org/dalt

- The calculator works on any device with web access. Computer/i-phone, pod, pad/Smart phones (blackberry, Droid, etc.)

New Standard

- SMACNA is developing a System Air Leakage Test Standard
  - With greater focus on CX and “whole building performance” this standard is needed
  - DALT is being misapplied so we need SALT
  - Will be co-sponsored by ASHRAE
  - Goal is to provide MOT and Pass/Fail criteria
  - TASK FORCE is comprised of SMACNA, ASHRAE, and AHRI members

Update to Existing Standards

- SMACNA published a new Duct leakage manual
- It is an ANSI standard
- Uses leakage class
- Leakage classes have been reduced

Thank You

Questions

&

Answers

Extra Info

- The following slides provide information on how to convert between leakage class and percent

- Also included are slides indicating the impact of reducing the allowable leakage from the first to second edition of the SMACNA standard

Leakage as % to Air Flow

Leakage Class	System Airflow cfm/ft²	System Airflow l/s per m2	Static Pressure in. wg (Pa) ½ (125)	1 (250)	2 (500)	3 (750)	4 (1000)	6 (1500)
48	2	10	15	24	38			
	2.5	12.7	12	19	30			
	3	15	10	16	25			
	4	20	7.7	12	19			
	5	25	6.1	9.6	15			
24	2	10	7.7	12	19			
	2.5	12.7	6.1	9.6	15			
	3	15	5.1	8.0	13			
	4	20	3.8	6.0	9.4			
	5	25	3.1	4.8	7.5			
12	2	10	3.8	6	9.4	12		
	2.5	12.7	3.1	4.8	7.5	9.8		
	3	15	2.6	4.0	6.3	8.2		
	4	20	1.9	3.0	4.7	6.1		
	5	25	1.5	2.4	3.8	4.9		
6	2	10	1.9	3	4.7	6.1	7.4	9.6
	2.5	12.7	1.5	2.4	3.8	4.9	5.9	7.7
	3	15	1.3	2.0	3.1	4.1	4.9	6.4
	4	20	1.0	1.5	2.4	3.1	3.7	4.8
	5	25	.8	1.2	1.9	2.4	3.0	3.8
3	2	10	1.0	1.5	2.4	3.1	3.7	4.8
	2.5	12.7	.8	1.2	1.9	2.4	3.0	3.8
	3	15	.6	1.0	1.6	2.0	2.5	3.2
	4	20	.5	.8	1.3	1.6	2.0	2.6
	5	25	.4	.6	.9	1.2	1.5	1.9

Leakage as % to Air Flow

Leakage Class	System Airflow		Static Pressure in. wg (Pa)					
	cfm/ft^2	l/s per m2	½ (125)	1 (250)	2 (500)	3 (750)	4 (1000)	6 (1500)
6	2	10	1.9	3	4.7	6.1	7.4	9.6
	2.5	12.7	1.5	2.4	3.8	4.9	5.9	7.7
	3	15	1.3	2.0	3.1	4.1	4.9	6.4
	4	20	1.0	1.5	2.4	3.1	3.7	4.8
	5	25	.8	1.2	1.9	2.4	3.0	3.8
3	2	10	1.0	1.5	2.4	3.1	3.7	4.8
	2.5	12.7	.8	1.2	1.9	2.4	3.0	3.8
	3	15	.6	1.0	1.6	2.0	2.5	3.2
	4	20	.5	.8	1.3	1.6	2.0	2.6
	5	25	.4	.6	.9	1.2	1.5	1.9

Convert Leakage Class to % of Flow?

- First you need some information about the system
  - Fan 8,000 CFM (operating conditions)
  - 333 linear feet of duct
  - 1,926 ft^2 of duct surface area
  - Leakage class 8 required
  - ½ in. w.g. test pressure
  - 4.15 cfm/ft^2 surface area (airflow not leakage)

Convert Leakage Class to % of Flow?

- Use Figure 5-1 or

$F = C_L\ P^{0.65}$ (CFM/100ft^2)

$$F = \frac{5.1cfm}{100\ ft^2}$$

- Determine allowable leakage

$$\frac{5.1cfm}{100\ ft^2} \times 1926\ ft^2 = 98.2cfm$$

- Determine % to flow

$$\frac{98.2cfm}{8000cfm} \times 100\% = 1.2\%$$

Convert % of Flow to Leakage Class?

- First you need some information about the system
  - Fan 8,000 CFM (operating conditions)
  - 333 linear feet of duct
  - 1,926 ft^2 of duct surface area
  - 5% required
  - 4 in. w.g. test pressure

Convert % of Flow to Leakage Class?

- Determine allowable leakage

$$.05 \times 8000 cfm = 400 cfm$$

- Express as cfm/100ft^2

$$\frac{400 cfm}{1926\ ft^2} \times 100\ ft^2 = 20.8 cfm$$

- Convert to Leakage Class C_L

$$C_L = \frac{F}{P^{0.65}} = \frac{20.8}{4^{0.65}} = \frac{20.8}{2.46} = 8.5$$

“New” Leakage Classes

- Public review has been completed.
- ANSI review has been completed.
- Compare % of Flow Difference
  Appendix A
- Compare Leakage Factor F
  (CFM/100ft^2 of duct surface area)
  Appendix E

LEAKAGE CLASS	FAN CFM PRORATED* PER S.F.	STATIC PRESSURE (IN WG)					
		½	1	2	3	4	6
48	2	15	24	38			
	2½	12	19	30			
	3	10	16	25			
	4	7.7	12	19			
	5	6.1	9.6	15			
24	2	7.7	12	19			
	2½	6.1	9.6	15			
	3	5.1	8.0	13			
	4	3.8	6.0	9.4			
	5	3.1	4.8	7.5			
12	2	3.8	6	9.4	12		
	2½	3.1	4.8	7.5	9.8		
	3	2.6	4.0	6.3	8.2		
	4	1.9	3.0	4.7	6.1		
	5	1.5	2.4	3.8	4.9		
6	2	1.9	3	4.7	6.1	7.4	9.6
	2½	1.5	2.4	3.8	4.9	5.9	7.7
	3	1.3	2.0	3.1	4.1	4.9	6.4
	4	1.0	1.5	2.4	3.1	3.7	4.8
	5	0.8	1.2	1.9	2.4	3.0	3.8
3	2	1.0	1.5	2.4	3.1	3.7	4.8
	2½	0.8	1.2	1.9	2.4	3.0	3.8
	3	0.6	1.0	1.6	2.0	2.5	3.2
	4	0.5	0.8	1.3	1.6	2.0	2.6
	5	0.4	0.6	0.9	1.2	1.5	1.9

% to System Airflow

Leakage Class (C_L)	Fan cfm Prorated* per ft^2	Static Pressure (in. wg)						
		½	1	2	3	4	6	10
48	2	15	24	38				
	2.5	12	19	30				
	3	10	16	25				
	4	7.6	12	19				
	5	6.1	9.6	15				
16	2	5.1	8.0	13	16			
	2.5	4.1	6.4	10	13			
	3	3.4	5.3	8.4	11			
	4	2.5	4.0	6.3	8.2			
	5	2.0	3.2	5.0	6.5			
8	2	2.5	4.0	6.3	8.2	9.8		
	2.5	2.0	3.2	5.0	6.5	7.9		
	3	1.7	2.7	4.2	5.4	6.6		
	4	1.3	2.0	3.1	4.1	4.9		
	5	1.0	1.6	2.5	3.3	3.9		
4	2	1.3	2.0	3.1	4.1	4.9	6.4	8.9
	2.5	1.0	1.6	2.5	3.3	3.9	5.1	7.1
	3	0.8	1.3	2.1	2.7	3.3	4.3	6.0
	4	0.6	1.0	1.6	2.0	2.5	3.2	4.5
	5	0.5	0.8	1.3	1.6	2.0	2.6	3.6
2	2	0.6	1.0	1.6	2.0	2.5	3.2	4.5
	2.5	0.5	0.8	1.3	1.6	2.0	2.6	3.6
	3	0.4	0.7	1.0	1.4	1.6	2.1	3.0
	4	0.3	0.5	0.8	1.0	1.2	1.6	2.2
	5	0.3	0.4	0.6	0.8	1.0	1.3	1.8

% to System Airflow

PRESSURE W.G.		LEAKAGE CLASS (C_L)				UNSEALED
$P^{0.65}$	P"	CLASS 3	CLASS 6	CLASS 12	CLASS 24	CLASS 48
0.143	0.05	0.4	0.9	1.7	3.4	6.7
0.224	0.10	0.7	1.3	2.7	5.4	10.7
0.351	0.20	1.1	2.1	4.2	8.4	16.8
0.457	0.30	1.4	2.7	5.5	11.0	21.9
0.551	0.40	1.7	3.3	6.6	13.2	26.4
0.637	0.50	1.9	3.8	7.6	15.3	30.6
0.717	0.60	2.2	4.3	8.6	17.2	34.4
0.793	0.70	2.4	4.8	9.5	19.0	38.1
0.865	0.80	2.6	5.2	10.4	20.8	41.5
0.934	0.90	2.8	5.6	11.2	22.4	44.8
1	1	3	6	12	24	48
1.30	1.5	3.9	7.8	15.6	31.2	62.4
1.57	2.0	4.7	9.4	18.8	37.7	75.4
1.81	2.5	5.4	10.9	21.7	43.4	86.8
2.04	3.0	6.1	12.2	24.5	49.0	98.0
2.26	3.5	6.7	13.6	27.1	54.2	108.5
2.46	4.0	7.4	14.8	29.5	59.0	118.1
2.66	4.5	8.0	16.0			
2.85	5.0	8.6	17.1			
3.03	5.5	9.1	18.2			
3.20	6.0	9.6	19.2			
3.54	7.0	10.6	21.2			
3.86	8.0	11.6	23.2			
4.17	9.0	12.5	25.0			
4.47	10.0	13.4	26.8			
4.75	11.0	14.3	28.5			

$$C_L = \frac{F}{P^{0.65}}$$

When $P = 1$

$$C_L = F$$

$$F = C_L(P)^{0.65}$$

Pressure (P) in. wg	$P^{0.65}$	Leakage Class (C_L)				Unsealed
		Class 2	Class 4	Class 8	Class 16	Class 48
0.05	0.143	0.3	0.6	1.1	2.3	6.8
0.1	0.224	0.4	0.9	1.8	3.6	10.7
0.2	0.351	0.7	1.4	2.8	5.6	16.9
0.3	0.457	0.9	1.8	3.7	7.3	21.9
0.4	0.551	1.1	2.2	4.4	8.8	26.5
0.5	0.637	1.3	2.5	5.1	10.2	30.6
0.6	0.717	1.4	2.9	5.7	11.5	34.4
0.7	0.793	1.6	3.2	6.3	12.7	38.1
0.8	0.865	1.7	3.5	6.9	13.8	41.5
0.9	0.934	1.9	3.7	7.5	14.9	44.8
1.0	1.00	2.0	4.0	8.0	16.0	48.0
1.5	1.30	2.6	5.2	10.4	20.8	62.5
2.0	1.57	3.1	6.3	12.6	25.1	75.3
2.5	1.81	3.6	7.3	14.5	29.0	87.1
3.0	2.04	4.1	8.2	16.3	32.7	98.0
3.5	2.26	4.5	9.0	18.1	36.1	108.4
4.0	2.46	4.9	9.8			
4.5	2.66	5.3	10.6			
5.0	2.85	5.7	11.4			
5.5	3.03	6.1	12.1			
6.0	3.20	6.4	12.8			
7.0	3.54	7.1	14.2			
8.0	3.86	7.7	15.5			
9.0	4.17	8.3	16.7			
10.0	4.47	8.9	17.9			
11.0	4.75	9.5	19.0			

CFM/100ft^2

$$F = C_L (P^{0.65})$$