Connecticut ASHRAE

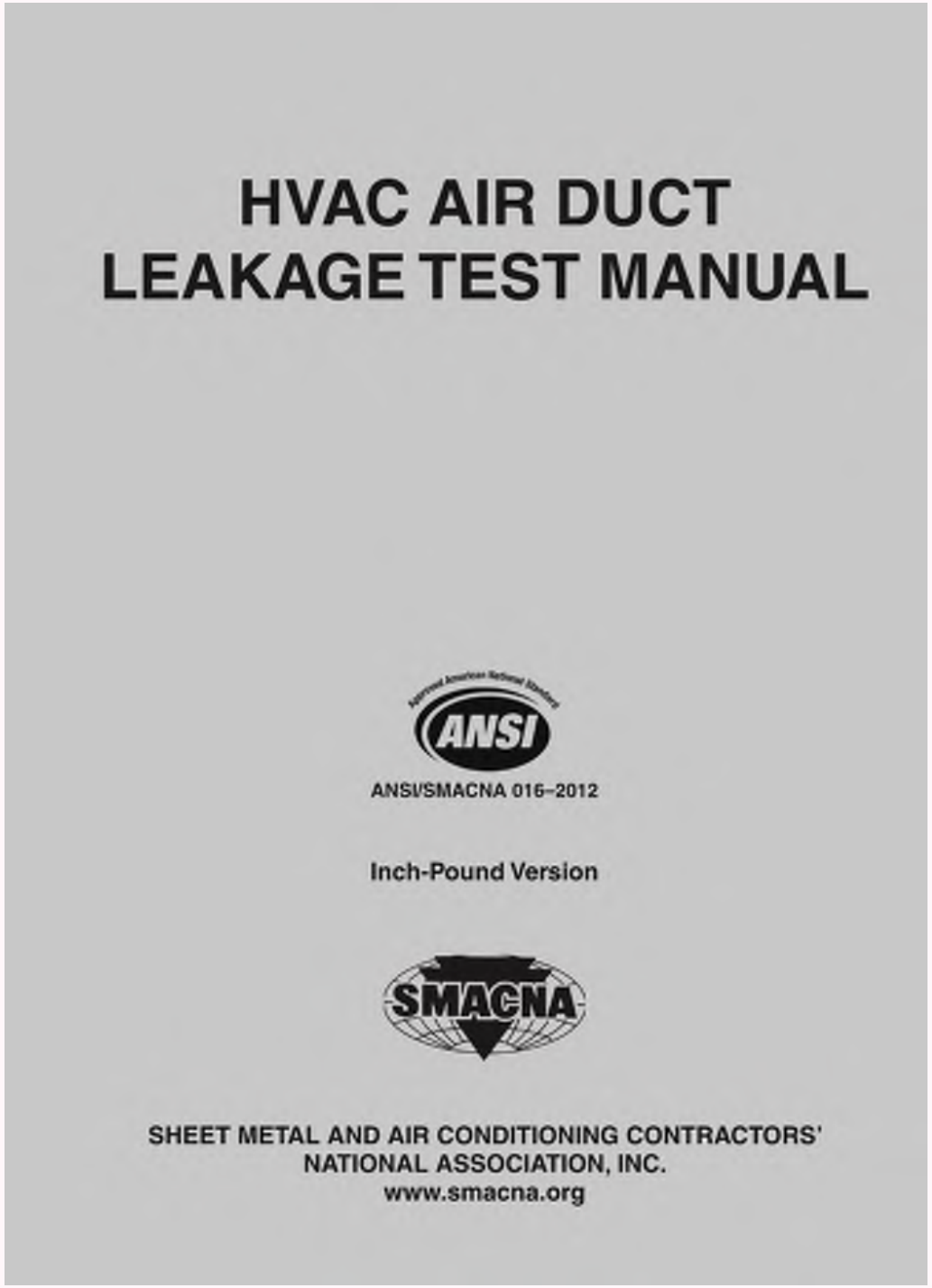
Tech Session

Duct and System Air Leakage

December 12, 2024

HVAC Air Duct Leakage Test Standard

- Published in 2012
- Standard for Testing Leakage of Air from Ductwork (only).



System Air Leakage Test Standard

- Published in 2020
- Provides “Pass or Fail” Criteria for “Systems”, not just Ductwork

Duct Leakage Testing:

- Related SMACNA Publications
  - SMACNA HVAC Duct Construction Standards (4th Ed.)
  - SMACNA HVAC Air Duct Leakage Test Manual (DALT)
  - **SMACNA System Air Leakage Testing Manual (SALT)**

NOTE: The publications above ***do not*** require leakage tests

- **The Professionals of Record carry the responsibility to clearly outline when testing is required.**
- **The Local Authority having Jurisdiction may require testing**

Definitions and Terms:

Duct Leakage

- The leakage of air from ductwork
- Includes Straight Duct and Fittings (ONLY)

- *Does not include* Accessories
  - Volume Dampers and Control Dampers
  - Fire and Combination Fire / Smoke Dampers
  - Terminal Units
    - VAV Box
    - Venturi Valves
  - Access Doors

- *Does not Include* Equipment
  - Air Handler
  - Fan Coil Unit

Appendix G, G.1 lists common Equipment and Accessories

Definitions and Terms:

Equipment Leakage

- The leakage of air from equipment
  - Air Handler
  - Fan Coil Unit

- *Does not include* Ductwork
- *Does not Include* Accessories

Appendix G, G.1 lists common Equipment and Accessories

Definitions and Terms:

System Leakage

- The leakage of air from Equipment, plus
- The leakage of air from Accessories, plus
- The leakage of air from Ductwork

  - System Leakage ***is not*** Duct Leakage

Appendix G
G.1:

APPENDIX G COMMON EQUIPMENT AND ACCESSORIES

G.1 COMMON EQIPMENT AND ACCESSARY LISTS

Equipment

Air Conditioning Units
Air Handlers
Chilled Beam (ducted)
CRAC Units (ducted)
Dedicated Outdoor Air Units
Duct Furnaces
Energy Recovery Ventilators
Fans – Inline
Fan Coil Units
Furnace
HVAC Units
Make Up Air Units
Unit Ventilators (ducted)
VRF indoor Units (ducted)

Accessories

Air Filter Racks/Housings
Coils – Duct Mounted Chilled Water
Coils – Duct Mounted DX
Coils – Duct Mounted Heating Hot Water
Coils – Duct Mounted Steam
Coils – Electric Duct Heaters
Dampers – Backdraft
Dampers – Motorized
Dampers – Smoke/Fire
Dampers – Volume
Humidifier Distribution Tubes
Humidifiers – Duct Mounted
Mech Access Doors
Roof Curbs
Terminal Units
Smoke Detector – Ductwork
Sound Traps/Attenuators

Definitions and Terms:

Seal Class

- Defines *WHERE* duct sealant is to be applied
- Designated by a Letter (“A”, “B”, “C”)
- Three Seal Classes (4th Class would be “unsealed”)
  - Minimum Required by SMACNA HVAC-DCS
    - Class “C” – All Transverse Joints
    - Class “B” - All Transverse Joints and Longitudinal Seams
    - Class “A” - All Transverse Joints, Seams & Applicable Penetrations

Note: Each Seal Class has additional requirements

Definitions and Terms:

Seal Class “C”

- **All Transverse Joints**

- Required at 2” w.g. (+/-)
- Required at any VAV system 1” and 1/2” w.g. upstream of the VAV boxes

Definitions and Terms:

Seal Class “B”

- **All Transverse Joints**
- **All Longitudinal Seams**

- Required at 3” w.g. (+/-)
- Spiral Seams are ***Exempt***

Definitions and Terms:

Seal Class “A”

- **All Transverse Joints**
- **All Longitudinal Seams**
- **All Applicable Penetrations**

- Required at 4” w.g. and up (+/-)
- Screws ***are not*** required to be sealed, but may be necessary to achieve successful testing

Definitions and Terms:

Seal Class	Sealing Requirements	Applicable Static Pressure Construction Class
A	Class A: All Transverse joints, longitudinal seams, and duct wall penetrations	4 in. wg and up (1000 Pa)
B	Class B: All Transverse joints and longitudinal seams only	3 in. wg (750 Pa)
C	Class C: Transverse joints only	2 in. wg (500 Pa)
In addition to the above, any variable air volume systems duct of 1 in. (250 Pa) and ½ in. wg (125 PA) construction class that is upstream of the VAV boxes shall meet Seal Class C.		

Table 1–1 Standard Duct Sealing Requirements

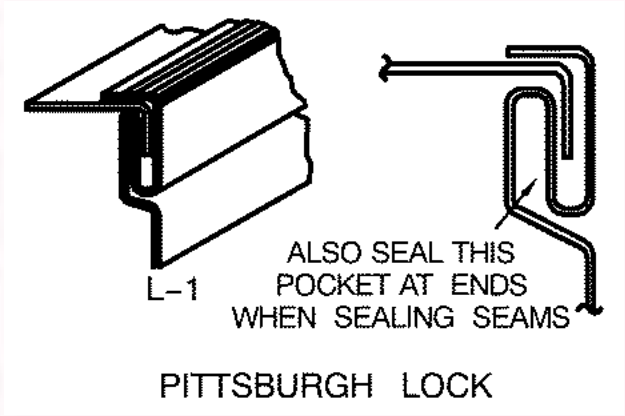
Definitions and Terms:

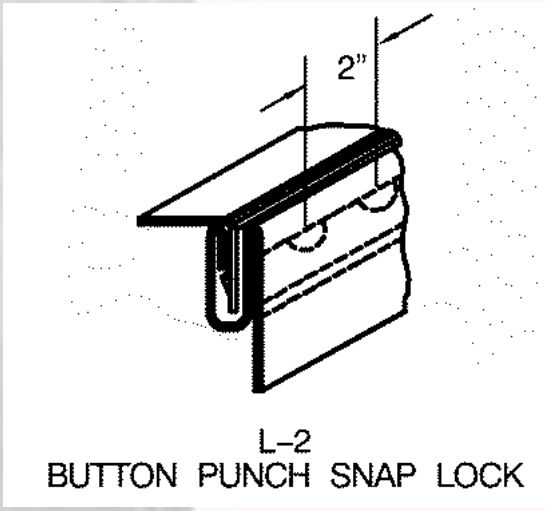
Longitudinal Seams

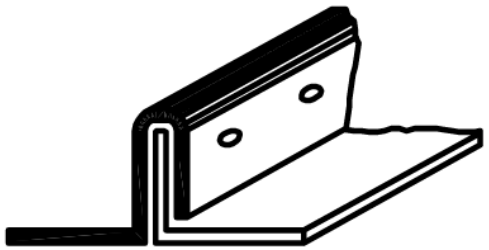
- Defined as joining of two longitudinally (in the direction of airflow) oriented edges of duct surface material occurring between two joints.
  - Includes “helical” seams (Spiral) - which again are exempt from sealing.

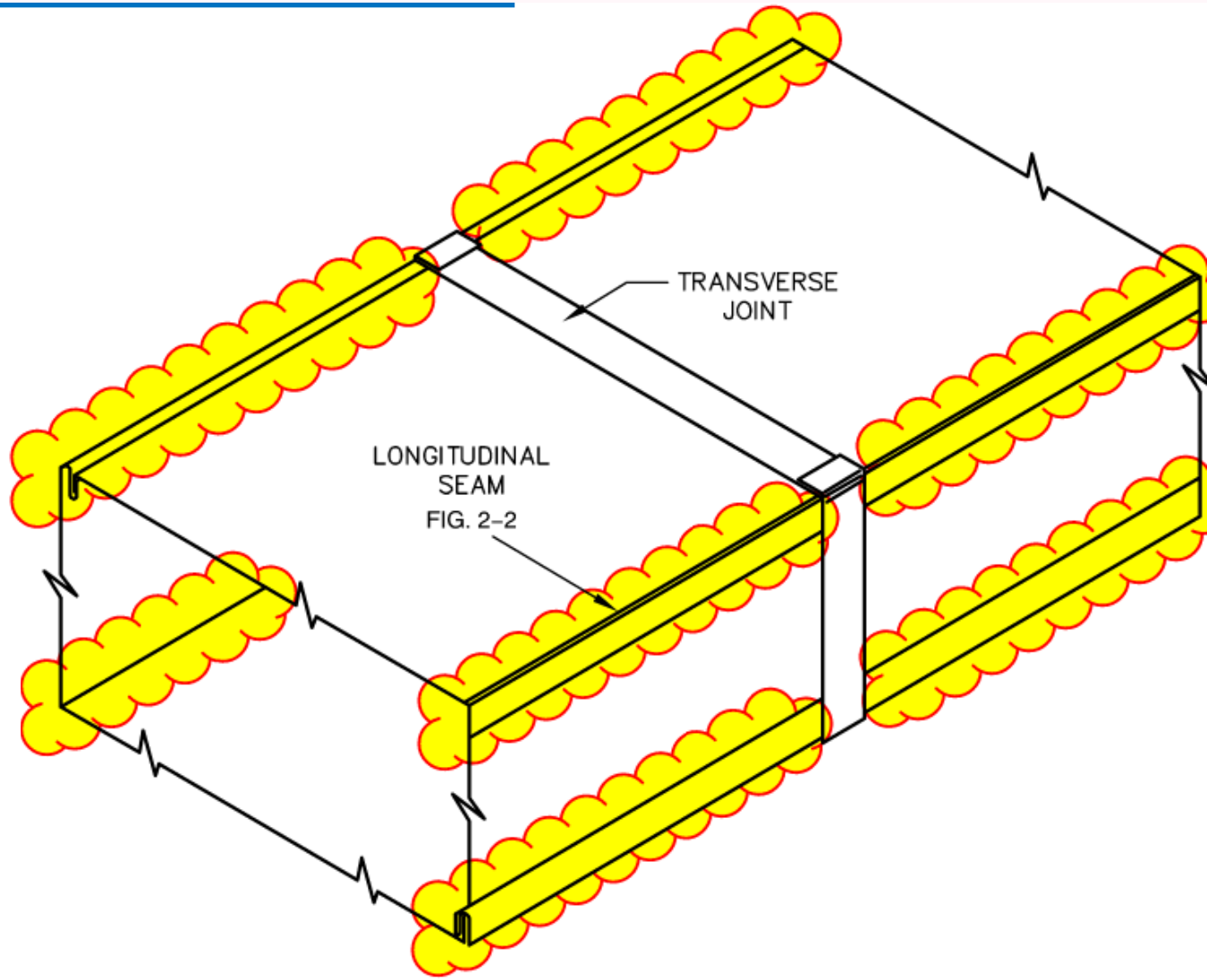
Definitions and Terms:

Longitudinal Seams









Definitions and Terms:

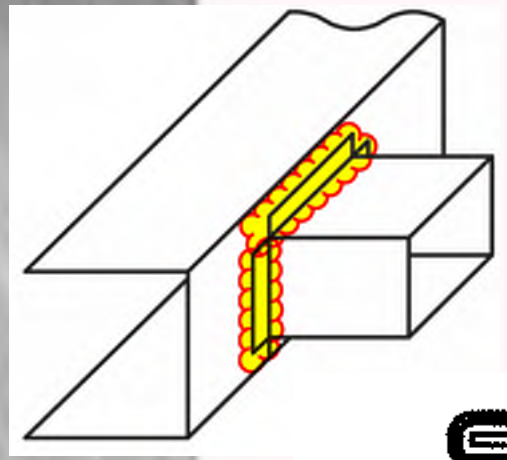
Transverse Joints

- All other duct wall connections are deemed to be Joints

- ❑ Girth Joints:
  - Joining two sections of ducts
- ❑ Branch and Sub-branch intersections
- ❑ Duct Collar Tap-ins, Fitting sub-sections
- ❑ Louver and Air Terminal connections to ducts
- ❑ Access Door and Access Panel FRAMES
- ❑ Abutments to building structures
  - Plenums / Fresh Air Intakes

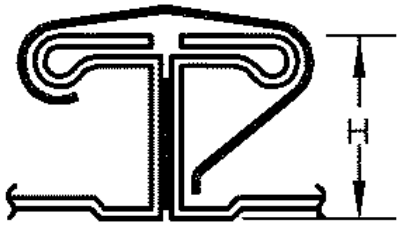
Definitions and Terms:

Transverse Joints

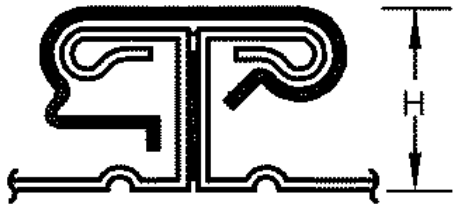


PLAIN "S" SLIP
T–5

DRIVE SLIP
T–1



FLANGED
(WITH GASKET)
T–25a



FLANGED
(WITH GASKET)
T–25b

Definitions and Terms:

Penetrations:

- Pipe, tubing, rod, and wire.
- Screws and other fasteners are ***NOT*** considered to be ductwork penetrations (in the context of leakage testing) when referring to seal class A.

Duct Leakage Factors:

The factors that determine how much a given duct leaks:

- ❑ Type of construction (joint/seam choices)
- ❑ The number of seams and joints (amount of duct)
- ❑ Static pressure
- ❑ Openings / penetrations
- ❑ Sealant
- ❑ Workmanship

History of Duct Leakage Testing:

- SMACNA has had some form of duct leakage testing since the 1960's
  - Based on Percentage (%) of flow
- 1985 SMACNA's first stand-alone leakage standard
  - Uses Leakage Class
  - Applies only to Duct
    - Accessories were not included
- 2012 SMACNA updated the Duct Leakage Standard
  - Reduced allowable leakage rates
    - Technological advances allowed the baseline to be decreased
- **2020** SMACNA releases a System Leakage Standard

History of Duct Leakage Testing:

1985 (1st Edition)

DUCT CLASS	½", 1", 2" wg	3" wg	4", 6", 10" wg
SEAL CLASS	C	B	A
SEALING APPLICABLE	TRANSVERSE JOINTS ONLY	TRANSVERSE JOINTS AND SEAMS	JOINTS, SEAMS AND ALL WALL PENETRATIONS
LEAKAGE CLASS			
RECTANGULAR METAL	24	12	6
ROUND METAL	12	6	3

Table 4-1 Applicable Leakage Classes

2012 (2nd Edition)

Duct Class	½ in., 1 in., 2 in. wg	3 in. wg	4 in., 6 in., 10 in. wg
Seal Class	C	B	A
Sealing Applicable	Transverse Joints Only	Transverse Joints and Seams	Joints, Seams and all Applicable Wall Penetrations
Leakage Class			
Rectangular Metal	16	8	4
Round Metal	8	4	2

Table 5–1 Recommended Leakage Classes

History of Duct Leakage Testing:

Research - 1972

- 1972 Research Project
  - Funded by the American Iron and Steel Institute & SMACNA
- Results:
  - Leakage from Seams is “negligible” when compared to leakage from Transverse joints
  - Air Velocity through the duct had “negligible” effect on leakage
  - Panel Gage had a “negligible” effect on leakage
  - “Slip & Drive” joint leakage was significant compared to the perimeter for “small duct”
  - Pocket Locks (Government Lock) leak more than “Slip & Drive”
  - Leakage is a function of Pressure

History of Duct Leakage Testing:

Research - 1985

- 1985: SMACNA Releases the HVAC Air Duct Leakage Test Manual
  - Uses Surface Area and Pressure
  - Focuses Testing on "higher pressure" ***over 3 in. w.g***.
  - Recommends testing a portion of duct
    - 25% of duct over 3 in. w.g.
  - Credit's Europe for using surface area and pressure

  - Important Quotes from DALT Publication
    - "SMACNA has concluded this approach is far superior to the arbitrary assignment of a percentage of fan flow rate as a leakage criteria."
    - "..industry fails to recognize the extent that equipment that is inserted in-line in duct leaks."
    - "Designers must account for equipment leakage separately from duct leakage allowances as they evaluate system leakage."

History of Duct Leakage Testing:

Research – 2000 +

- Y2K to Present
  - "Green Construction"
    - Pushed for better energy efficiency; Ductwork Leakage *"attacked"* (yet again)
      - Research Papers started calling it "Duct Leakage"
        - Included non-duct components (AHU's, VAV's, etc.)
- SMACNA pressures industry to separate "Duct" and "System" Leakage
  - 2012 SMACNA updates the DALT Manual
    - Updated the allowable leakage amounts (decreased values)
- Updates to Code and Standards
  - Most are in line with SMACNA
    - Still no significant requirements (Code) for "non-duct" components
    - Some in industry suggesting/requiring leakage rates
      - This approach still uses arbitrary values

History of Duct Leakage Testing:

Moving Forward…

- ASHRAE 90.1 (2019) Standard
  - Applies to Ductwork in Excess of 3 in. w.g.
  - All ductwork located outdoors
  - Testing of representative sections totaling no less than 25%
  - Sections designated by the Building Owner or Designated Rep.
  - Positive Pressure leakage testing is acceptable for negative ductwork

History of Duct Leakage Testing:

Moving Forward…

- IECC (International Energy Conservation Code) 2021
  - C403.12.2.3 High Pressure Duct Systems (Mandatory)
    - Applies to Ductwork equal to or greater than 3 in. w.g.
    - Leak Testing per SMACNA DALT Manual
    - Air Leakage Class = 4.0
  - Documentation shall be furnished to the designer, demonstrating:
    - No less than 25% of represented sections have been tested
    - All test sections comply with the requirements of this section

History of Duct Leakage Testing:

Moving Forward…

- UMC (Uniform Mechanical Code) 2024
  - 603.9.2: Duct Leakage Tests
    - Applies to ALL Ductwork
    - Leak Testing per SMACNA DALT Manual
    - No less than 10% of the total installed duct area shall be tested
      - If the tested sections fail to comply, 40% must be tested
      - If the second test fails, 100% of the duct shall be tested
    - Air Leakage Class = 6.0 (1st time this has been in a Base Code)
    - Testing Sections designated by the Building Owner or Designated Rep.

Building Code Requirement Summary

ICC Model Building Code

- International Energy Conservation Code
- C403.12.2.3 High Pressure Duct Systems (Mandatory)
- Applies to Ductwork equal to or greater than 3 in. w.g.
- Air Leakage Class = 4.0

ASHRAE Standard 90.1

- Applies to Ductwork in Excess of 3 in. w.g.
- All ductwork located outdoors
- Testing of representative sections totaling no less than 25%

Uniform Mechanical Code

- 603.9.2: Duct Leakage Tests
- Applies to ALL Ductwork
- No less than 10% of the total installed duct area shall be tested
- Air Leakage Class = 6.0

History of Duct Leakage Testing:

- Building Code Requirements
  - To date no code has adopted a “system test” requirement
  - ***All*** codes use a Leakage Class (for commercial duct systems)
  - ***None*** require all the duct to be tested
  - ***None*** require testing at elevated pressures

System Air Leakage Test Standard

- Published in 2020
- Provides “Pass or Fail” Criteria
- Addresses “System Leakage”

System Air Leakage Test Standard:

DALT vs SALT: What's the Same?

- The test method is the same
  - Cap, pressurize, measure
- Leakage rates for duct are the same
  - Leakage Class is used, same as 2012 DALT Manual
- Test sections can be of varying sizes
  - Limited only by the equipment and other jobsite conditions
- Pass / Fail is a function of Pressure and "Quantity"
  - Surface area or quantity of items (accessories, equip.)
- Testing can be conducted once section is complete
  - Whole system does not need to be installed / functional

System Air Leakage Test Standard:

DALT vs SALT: What's Different?

- No longer holding a "line" at 3 in. w.g
  - Industry is moving away from this…
    - Systems are operating at lower pressures
    - Still need Judicious requirements for testing
- Now includes information on "non-ducted" items
  - FSD
  - Terminal Boxes
- Includes a method to determine Pass/Fail for system or sub-system
- Now has a "Challenge" option (Isolated Test)
  - Allows contractor to challenge the Pass/Fail assigned by specification

System Air Leakage Test Standard:

DALT vs SALT: What's Excluded?

- Grease Duct Systems
  - Light Test (*** likely phasing out)
  - Water Test
  - Pressure Test

- Smoke Control Systems
  - Codes typically dictate 5% leakage at 1.5 x Pressure
    - SMACNA does not agree with this approach
    - Few issues have been reported from Members

- Industrial Duct Systems
  - May be used dependent upon:
    - Specification
    - Application
    - Construction Type

System Air Leakage Test Standard:

Why Using Percentage (%) of Airflow is Wrong

Testing Data has shown that following:

- Leakage is a function of Pressure, not Airflow
- Airflow is negligible to leakage

System Air Leakage Test Standard:

Converting Percentage (%) of Airflow is Wrong

All applicable Codes and Standards use a Leakage Class for duct, *not* a percentage of airflow:

- **ASHRAE 90.1**
  - Leakage Class = 4.0
- **IECC**
  - Leakage Class = 4.0
- **IAPMO UMC**
  - Leakage Class = 6.0

System Air Leakage Test Standard:

Converting Percentage (%) of Airflow to Leakage Class

- Determine the Total Flow for the “System”
  - Supply Side or Return Side, *NOT both*
- Determine the total surface area
- Determine the Pass / Fail criteria using the specified percent (%)
- Determine the Test Pressure

Using the data from above, the Leakage Class can be established

Note: Works for duct (only), no way to account for other components

Let’s look at an example!

System Air Leakage Test Standard:

Converting (%) of Airflow to Leakage Class: Example #1

- Design Flow (supply) = 115,000 CFM
- Surface Area = 21,557 ft²
- Specified Leakage = 2.5%
- Test Pressure = 2.5 in. w.g.

- Determine the Allowable Leakage
  - 2.5% x 115,000 CFM = 2,875 CFM

- Convert the % of CFM to the Duct Leakage Factor
  - "F_D" = (CFM/100ft²)
  - 2,875 ÷ 21,557x 100 = 13.34
  - Duct Leakage Factor = 13.34

System Air Leakage Test Standard:

Example #1: Convert the Leakage Factor to Leakage Class

- Formulas:
  - $F_D = C_L \times P^N$
  - $C_L = F_D \div P^N$
    - $F_D = 13.34$
    - $P = 2.5$
  - $C_L = 13.34 \div (2.5)^{0.65}$
  - $C_L = 7.35$

Formula Nomenclature:

F_D = Duct Leakage Factor

C_L = Leakage Class

P = Test Static Pressure

N = Duct Coefficient (0.65)

- Solution:
  - The Leakage Class is 7.35
  - This should be achievable as it's well above Class 4
- Suggestion:
  - Proceed using SMACNA Standards
  - Consider Leakage Class 4

System Air Leakage Test Standard:

Example #2: Converting (%) of Airflow to Leakage Class

- Design Flow (exhaust) = 7,000 CFM
- Surface Area = 6,813 ft²
- Specified Leakage = 2.5%
- Test Pressure = 2.0 in. w.g.

- Determine the Allowable Leakage
  - 2.5% x 7,000 CFM = 175 CFM

- Convert the % of CFM to the Duct Leakage Factor
  - "F_D" = (CFM/100ft²)
  - 175 ÷ 6,813 x 100 = 2.57
  - Duct Leakage Factor = 2.57

System Air Leakage Test Standard:

Example #2: Convert the Leakage Factor to Leakage Class

- Formulas:
  - $F_D = C_L \times P^N$
  - $C_L = F_D \div P^{0.65}$
    - $F_D = 2.57$
    - $P = 2.0$
  - $C_L = 2.57 \div (2.0)^{0.65}$
  - $C_L = 1.64$

Formula Nomenclature:

F_D = Duct Leakage Factor
C_L = Leakage Class
P = Test Static Pressure
N = Duct Coefficient (0.65)

- Solution:
  - The Leakage Class is 1.64
  - This is well below what SMACNA would expect
    - Class 2 is possible, but not likely for a rectangular duct system
- Suggestion:
  - Proceed using SMACNA Standards – Notify E.O.R.
  - Consider Leakage Class 4

System Air Leakage Test Standard:

Converting (%) of Airflow to Leakage Class:

What are the impacts if we use the Leakage Class 4 compared to 2.5%?

- In Example #2 the exhaust duct was to be tested at 2 in w.g. with 2.5% allowable leakage (175 cfm)
  - **Now let's use the same example but test to Leakage Class 4 vs 2.5%**
- Example #3
  - We will use a **Leakage Class 4** and a **Test Pressure of 2.0 in. w.g.** for the Exhaust Ductwork in Example #2

System Air Leakage Test Standard:

Example #3

Calculate Allowable Leakage using Leakage Class 4

- Design Flow (exhaust) = 7,000 CFM
- Surface Area = 6,813 ft^2
- Specified Leakage = 2.5%
- Test Pressure = 2.0 in. w.g.

1. Determine the Allowable Leakage
   - 2.5% x 7,000 CFM = 175 CFM

System Air Leakage Test Standard:

Example #3

Calculate Allowable Leakage using Leakage Class 4

- Formulas:
  - $F_D = C_L \times P^N$
    - $C_L = 4$
    - $P = 2.0$
  - $F_D = 4 \times (2.0)^{0.65}$
  - $F_D = 6.28$ CFM / 100Ft^2
  - $F_D = 6.28$
- Solution:
  - The Duct Leakage Factor = 6.28

Formula Nomenclature:

L_D = Allowable Duct Leakage
F_D = Duct Leakage Factor
C_L = Leakage Class
P = Test Static Pressure
N = Duct Coefficient (0.65)

System Air Leakage Test Standard:

Example #3

Calculate Allowable Leakage using Leakage Class 4

- Formulas:
  - $L_D = S_D \times F_D \div 100$ (IP Only)
    - $S_D = 6{,}813\ Ft^2$
    - $F_D = 6.28$
  - $L_D = 6{,}813 \times 6.28 \div 100$
  - $L_D = 8{,}857 \div 100 Ft^2$
  - $L_D = 427.85$ CFM
- Solution:
  - The Allowable Duct Leakage = 427.85 CFM

Formula Nomenclature:

L_D = Allowable Duct Leakage
F_D = Duct Leakage Factor
C_L = Leakage Class
P = Test Static Pressure
N = Duct Coefficient (0.65)

Example #3 vs Example #2

Example #2 (Percentage)

- Design Flow (exhaust) = 7,000 CFM
- Surface Area = 6,813 ft^2
- Specified Leakage = 2.5%
- Test Pressure = 2.0 in. w.g.

- Determine the Allowable Leakage
  - 2.5% x 7,000 CFM = 175 CFM

- Solution:
  - Duct Leakage Factor = 2.57
  - Allowable Leakage = 175 cfm
  - Leakage = 2.5%

Example #3 (Leakage Class)

- Design Flow (exhaust) = 7,000 CFM
- Surface Area = 6,813 ft^2
- Leakage Class = 4
- Test Pressure = 2.0 in. w.g.

- Determine the Allowable Leakage
  - $F_D = 4 \times (2.0)^{0.65}$
  - $F_D = 6.28$ CFM / $100Ft^2$
  - $F_D = 6.28$ (Leakage Factor)

- Solution:
  - The Duct Leakage Factor = 6.28
  - Allowable Leakage = 427.85 cfm
  - Leakage = 6.1%

Testing Procedure

- Step #1 – Select Test Pressure
  - Equivalent to the Duct Construction Class (i.e. 2 in. w.g.)
  - Not to Exceed the Pressure Class Rating of Any component included in the Section being Tested
    - Example:
      - Main Duct Trunk = 3 in. w.g. Construction
      - Sub-Duct = 2 in. w.g. Construction
    - Solution:
      - System to be tested at 2 in. w.g. or less

Testing Procedure

- Step #2 – Select Section of Duct to be Tested

- Ensure the Estimated Leakage will not exceed the capacity of the testing equipment

Testing Procedure

- Step #3 – Calculate Allowable Leakage (per Section)

Formula Nomenclature:

L_S = System Leakage
L_D = Duct Leakage
L_A = Accessory Leakage
L_E = Equipment Leakage

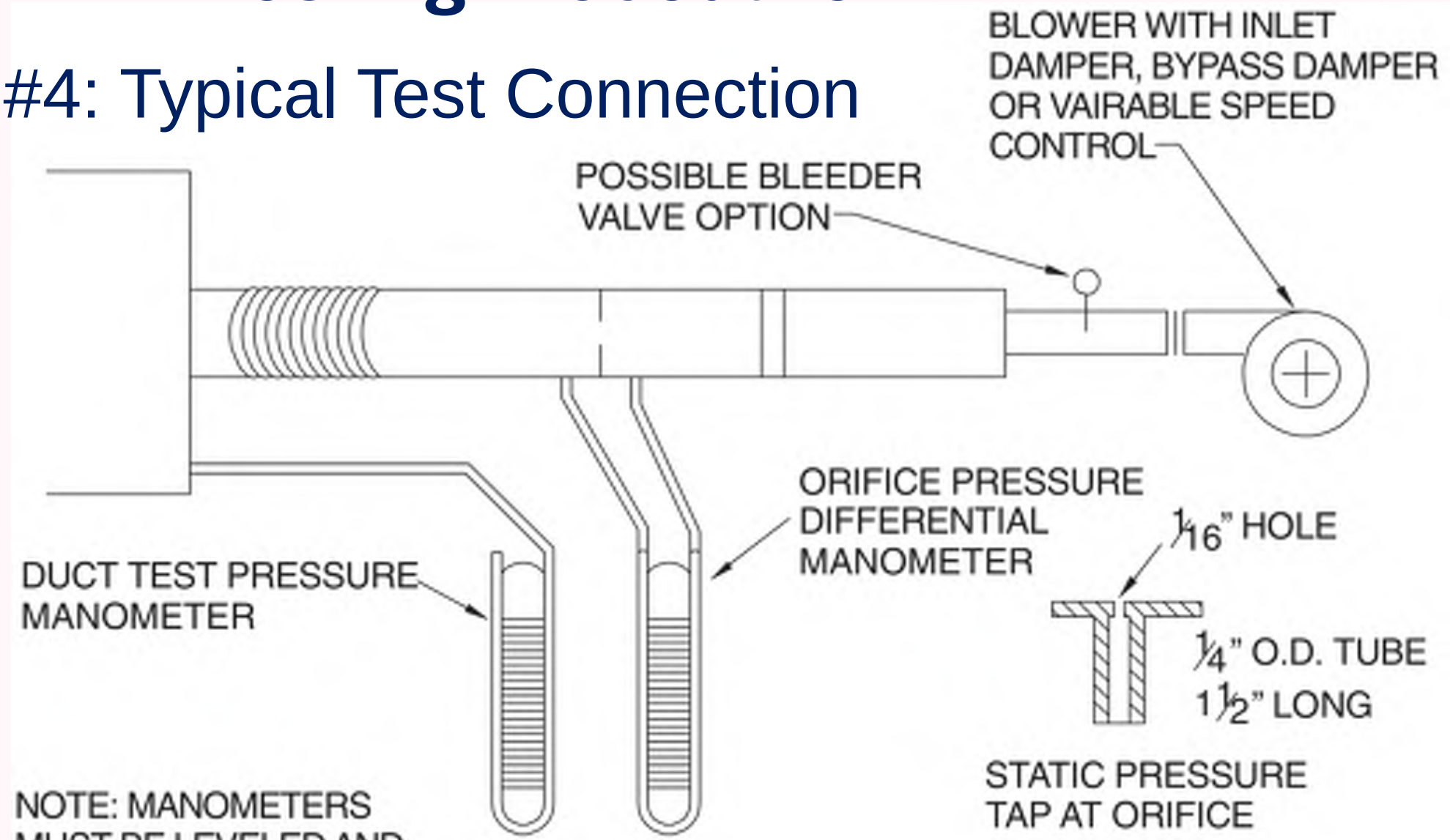
- Formula: $L_S = L_D + L_A + L_E$

Testing Procedure

- Step #4 – Connect Testing Equipment
  - Connect Blower and Flowmeter to Duct / Equipment
  - Temporarily Seal Connections
  - Temporarily Seal all open ends of ductwork, equipment and accessories

Testing Procedure

- Step #4: Typical Test Connection



Testing Procedure

- Step #5 – Pressurize the Test Section
  - Use Caution to prevent over pressurization of the Test Section
  - Start Blower with the variable inlet damper in the closed position
    - If VFD is used, begin on lowest frequency
  - Slowly increase Fan CFM to reach desired pressure level & pressure has stabilized

Testing Procedure

- Step #6 – Read / Record the Flowmeter
  - Record the ΔP (Pressure Differential)
    - Example: ΔP = 1.22 in.wg
  - Table 6-2: Orifice Flow Rate vs Pressure Differential
    - Table Provides quantity of lost airflow based on:
      - Pressure Differential, and
      - Orifice Size
        - Example: 1.4” Diameter Orifice

If Measured Leakage < Allowable Leakage = Successful Test

Testing Procedure

Table 6-2:

Orifice Flow Rate vs Pressure Differential

ΔP in. wg	Orifice Size 1.4"	2.625"	4.90"	ΔP in. wg	Orifice Size 1.4"	2.625"	4.90"	ΔP in. wg	Orifice Size 1.4"	2.625"	4.90"
0.02			57.1	1.22	28.7	101.4	410.3	4.10	52.3	185.3	746
0.04		18.7	78.8	1.24	28.9	102.3	413.6	4.20	52.9	187.5	755
0.06		22.8	95.3	1.26	29.2	103.1	416.9	4.30	53.5	189.7	763
0.08		26.2	109.2	1.28	29.4	103.9	420.1	4.40	54.1	191.9	772
0.10		29.3	121.5	1.30	29.6						
0.12		32.1	132.6	1.32	29.8						
0.14		34.6	142.8	1.34	30.1						
0.16		37.0	152.3	1.36	30.3						
0.18		39.2	161.2	1.38	30.5						
0.20		41.3	169.6	1.40	30.7						
0.22		43.3	177.6	1.42	30.9						
0.24		45.2	185.2	1.44	31.2						
0.26		47.0	192.6	1.46	31.4						
0.28		48.8	199.6	1.48	31.6						
0.30		50.5	206.5	1.50	31.8						
0.32		52.1	213.0	1.52	32.0	113.2	457.2	5.60	61.0	216.3	869

ΔP in. wg	1.4"
1.22	28.7

Testing Procedure

- Step #6 – Read / Record the Flowmeter
  - **If Measured Leakage > Allowable Leakage = Failed Test**
    - Inspect the Test Section for sensible leaks
    - Perform Smoke Test or use Leak Detection Products
    - Depressurize, Repair any leaks detected and allow sealant to cure
    - Begin decreasing Test Section until testing is successful

Testing Procedure

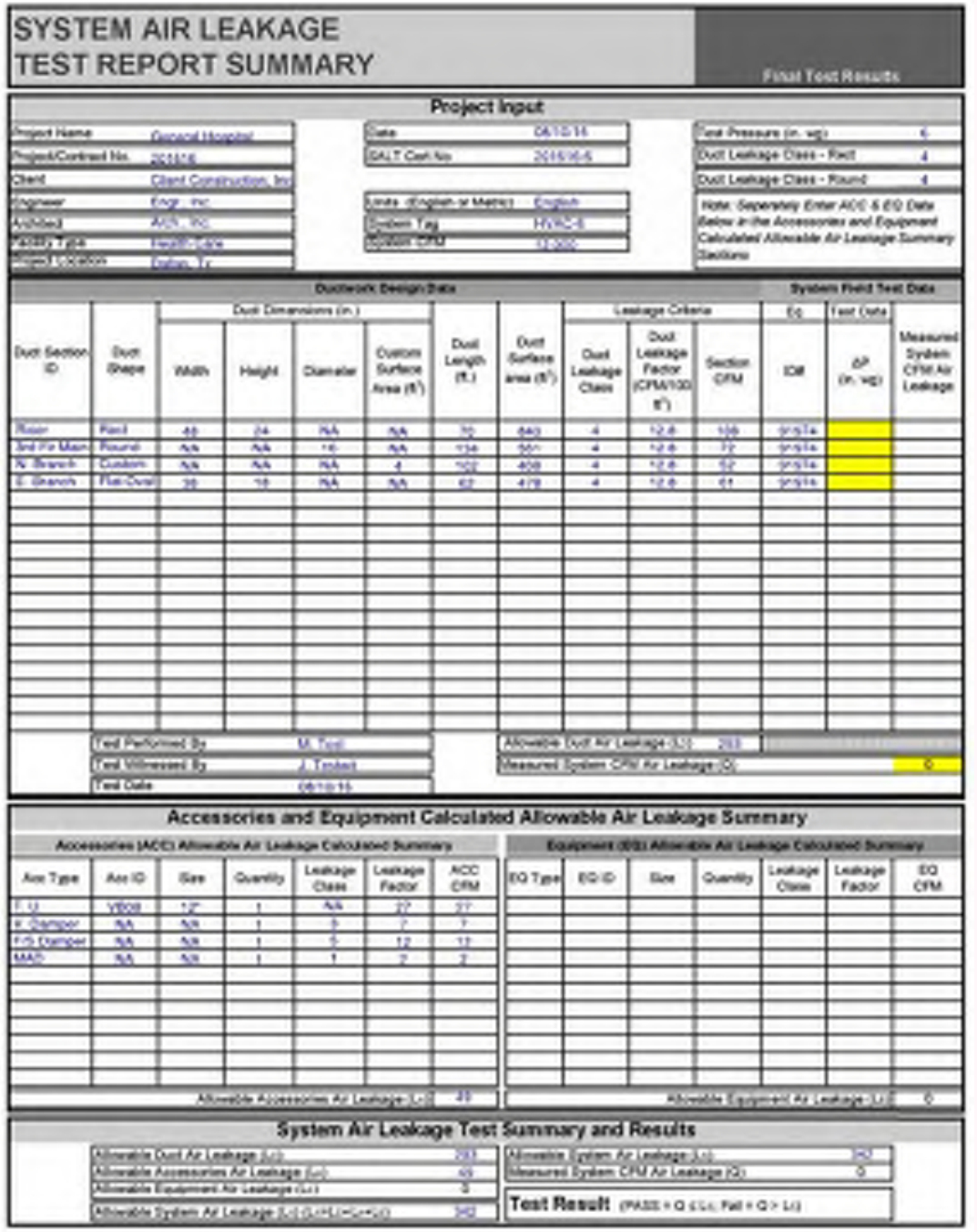
- Step #7 – Complete Test Reports
  - Fully Complete the Test Report Form
    - Do not leave any “blanks”
      - Fill in blanks with “N/A” or similar
  - Obtain “Witness” signature (if required)

Testing Procedure

- Step #8 – Remove Test Equip. & Materials
  - Temporary Plugs
  - Blank-off Panels and Seals

Testing Forms

- Figure 6-1 (Page 6.5)
- Reports can be prepared in advance
  - Project Information Section
  - Duct Section
  - Accessories Section
  - Equipment Section
- Defines Test Criteria in Pass / Fail Terms



SYSTEM AIR LEAKAGE
TEST REPORT SUMMARY

Final Test Results

Project Input

Ductwork Design Data | System Field Test Data

Duct Dimensions (in.) | Leakage Criteria | Eq | Test Data

Duct Section ID	Duct Shape	Width	Height	Diameter	Custom Surface Area (ft²)	Duct Length (ft.)	Duct Surface area (ft²)	Duct Leakage Class	Duct Leakage Factor (CFM/100 ft²)	Section CFM	ID#	ΔP (in. "wg)	Measured System CFM Air Leakage
Riser	Rect	48	24	NA	NA	70	640	4	12.8	136	9/3/14		
3rd Flr Main	Round	NA	NA	16	NA	134	561	4	12.8	72	9/3/14		
N. Branch	Custom	NA	NA	NA	4	102	408	4	12.8	52	9/3/14		
E. Branch	Flat Oval	28	16	NA	NA	62	478	4	12.8	61	9/3/14		

Test Performed By: M. Test
Test Witnessed By: J. Tester
Test Date: 08/10/15

Allowable Duct Air Leakage (La): 283
Measured System CFM Air Leakage (Q): 0

Accessories and Equipment Calculated Allowable Air Leakage Summary

Accessories (ACE) Allowable Air Leakage Calculated Summary | Equipment (EQ) Allowable Air Leakage Calculated Summary

Acc Type	Acc ID	Size	Quantity	Leakage Class	Leakage Factor	ACC CFM	EQ Type	EQ ID	Size	Quantity	Leakage Class	Leakage Factor	EQ CFM
T. U.	VBox	12"	1	NA	27	27							
# Damper	NA	NA	1	5	7	7							
FA Damper	NA	NA	1	5	12	12							
MAP	NA	NA	1	1	2	2							

Allowable Accessories Air Leakage (La): 49
Allowable Equipment Air Leakage (La): 0

System Air Leakage Test Summary and Results

Allowable Duct Air Leakage (La): 283
Allowable Accessories Air Leakage (La): 49
Allowable Equipment Air Leakage (La): 0
Allowable System Air Leakage (La): 332
Allowable System Air Leakage (La): 332
Measured System CFM Air Leakage (Q): 0
Test Result (PASS if Q ≤ La; Fail if Q > La)

FIGURE 6–1 SYSTEM AIR LEAKAGE TEST REPORT SUMMARY

Testing Forms

- Project Information Section

SYSTEM AIR LEAKAGE TEST REPORT SUMMARY

Final Test Results

Project Input

Project Name	General Hospital	Date	08/10/16	Test Pressure (in. wg)	6
Project/Contract No.	201616	SALT Cert No	201616-6	Duct Leakage Class - Rect	4
Client	Client Construction, Inc			Duct Leakage Class - Round	4
Engineer	Engr., Inc.	Units (English or Metric)	English	*Note: Seperately Enter ACC & EQ Data Below in the Accessories and Equipment Calculated Allowable Air Leakage Summary Sections*	
Architect	Arch., Inc.	System Tag	HVAC-6		
Facility Type	Health Care	System CFM	12,000		
Project Location	Dallas, Tx				

Testing Forms

- Ductwork Section

Ductwork Design Data												System Field Test Data		
Duct Section ID	Duct Shape	Duct Dimensions (in.)				Duct Length (ft.)	Duct Surface area (ft^2)	Leakage Criteria			Eq	Test Data	
		Width	Height	Diameter	Custom Surface Area (ft^2)			Duct Leakage Class	Duct Leakage Factor (CFM/100 ft^2)	Section CFM	ID#	ΔP (in. wg)	Measured System CFM Air Leakage
Riser	Rect	48	24	NA	NA	70	840	4	12.8	108	91974		
3rd Flr Main	Round	NA	NA	16	NA	134	561	4	12.8	72	91974		
N. Branch	Custom	NA	NA	NA	4	102	408	4	12.8	52	91974		
E. Branch	Flat Oval	36	18	NA	NA	62	478	4	12.8	61	91974		

Found in Appendix "A"

Test Performed By	M. Test	Allowable Duct Air Leakage (LD)	293
Test Witnessed By	J. Testwit	Measured System CFM Air Leakage (Q)	
Test Date	08/10/16		

Appendix A

- Duct Leakage Factors
- Test Pressure = 6 in. w.g.
- Leakage Class = 4
- Leakage Factor (F_D) = 12.8

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			

$$F_D = C_{LD}(P^{0.65})$$

Table A–1 Leakage Factor *F* Expressed As cfm/100ft² of Duct Surface Area

Testing Forms

- Accessories and Equipment

Accessories and Equipment Calculated Allowable Air Leakage Summary

Accessories (ACC) Allowable Air Leakage Calculated Summary

Acc Type	Acc ID	Size	Quantity	Leakage Class	Leakage Factor	ACC CFM
T. U.	VB08	12"	1	NA	27	27
V. Damper	NA	NA	1	3	7	7
F/S Damper	NA	NA	1	5	12	12
MAD	NA	NA	1	1	5	5
Allowable Accessories Air Leakage (L_A)						51

Equipment (EQ) Allowable Air Leakage Calculated Summary

EQ Type	EQ ID	Size	Quantity	Leakage Class	Leakage Factor	EQ CFM
Allowable Equipment Air Leakage (L_E)						0

Found in Appendix "B"

Appendix B

- **Terminal Units w/o Accessories**
- Inlet Size = 12 in.
- Test Pressure = 6 in. w.g.
- Leakage Factor (F_A) = 27

B.1.1 Terminal Units Without Accessory Heating Coils or Other Accessories

Inlet Size	Terminal Unit Casing Allowable Leakage CFM							
	1/4"	1/2" wg	1" wg	1 1/2" wg	2" wg	3" wg	4" wg	6" wg
4,5,6	4	5	8	9	11	13	15	19
7,8	4	6	8	10	12	14	17	20
9,10	5	7	10	12	12	13	17	19
12	5	8	11	13	16	19	22	27
14	7	10	14	17	19	23	27	33
16	8	11	15	19	21	26	30	37

TABLE B–1 TERMINAL UNIT CASING ALLOWABLE LEAKAGE

Accessories and Equipment Calculated Allowable Air Leakage Summary

Accessories (ACC) Allowable Air Leakage Calculated Summary

Acc Type	Acc ID	Size	Quantity	Leakage Class	Leakage Factor	ACC CFM
T. U.	VB08	12"	1	NA	27	27
V. Damper	NA	NA	1	3	7	7
F/S Damper	NA	NA	1	5	12	12
MAD	NA	NA	1	1	5	5
Allowable Accessories Air Leakage (L_A)						51

Equipment (EQ) Allowable Air Leakage Calculated Summary

EQ Type	EQ ID	Size	Quantity	Leakage Class	Leakage Factor	EQ CFM
Allowable Equipment Air Leakage (L_E)						0

Appendix B

- **Volume Control Dampers**
- Test Pressure = 6 in. w.g.
- Leakage Factor (F_A) = 7

B.2 VOLUME CONTROL DAMPERS

The following formula used with leakage test data is used to develop Volume Control Damper Allowable Leakage. Refer to Section 4.5.2.c:

$F_A = C_{LA} P^N$

$L_A = Q_A F_A$

Where:

F_A is the leakage from a single accessory
C_{LA} is accessory leakage class
P is test static pressure in. wg
^{N} is an exponent (.50 for ductwork accessories)
Q_A is quantity of the accessory
L_A is the amount of allowed leakage for a specific accessory

Volume Control Damper Allowable Duct Leakage CFM Each								
1/4" wg	1/2" wg	1" wg	1 1/2" wg	2" wg	3" wg	4" wg	6" wg	10" wg
2	2	3	4	4	5	6	7	9

TABLE B–8 VOLUME CONTROL DAMPER ALLOWABLE LEAKAGE

Accessories and Equipment Calculated Allowable Air Leakage Summary

Accessories (ACC) Allowable Air Leakage Calculated Summary						
Acc Type	Acc ID	Size	Quantity	Leakage Class	Leakage Factor	ACC CFM
T. U.	VB08	12"	1	NA	27	27
V. Damper	NA	NA	1	3	7	7
F/S Damper	NA	NA	1	5	12	12
MAD	NA	NA	1	1	5	5
Allowable Accessories Air Leakage (LA)						51

Equipment (EQ) Allowable Air Leakage Calculated Summary						
EQ Type	EQ ID	Size	Quantity	Leakage Class	Leakage Factor	EQ CFM
Allowable Equipment Air Leakage (LE)						0

Appendix B

- **Combo Fire / Smoke Dampers**
- Test Pressure = 6 in. w.g.
- Leakage Factor (F_A) = 12

B.3 SMOKE DAMPER AND COMBINATION FIRE & SMOKE DAMPER

The following formula used with leakage test data is used to develop Smoke Damper and Combination Fire & Smoke Damper Allowable Leakage. Refer to Section 4.5.2.c:

$F_A = C_{LA} P^N$

$L_A = Q_A F_A$

Where:

F_A is the leakage from a single accessory
C_{LA} is accessory leakage class
P is test pressure in in. wg
N is an exponent (.50 for ductwork accessories)
Q_A is quantity of the accessory
L_A is the amount of allowed leakage for a specific accessory

Smoke, Fire/Smoke Damper Allowable Duct Leakage CFM Each								
1/4" wg	1/2" wg	1" wg	1 1/2" wg	2" wg	3" wg	4" wg	6" wg	10" wg
3	4	5	6	7	9	10	12	16

TABLE B–9 SMOKE DAMPER AND COMBINATION FIRE & SMOKE DAMPER ALLOWABLE LEAKAGE

Accessories and Equipment Calculated Allowable Air Leakage Summary

Accessories (ACC) Allowable Air Leakage Calculated Summary						
Acc Type	Acc ID	Size	Quantity	Leakage Class	Leakage Factor	ACC CFM
T. U.	VB08	12"	1	NA	27	27
V. Damper	NA	NA	1	3	7	7
F/S Damper	NA	NA	1	5	12	12
MAD	NA	NA	1	1	5	5
Allowable Accessories Air Leakage (L_A)						51

Equipment (EQ) Allowable Air Leakage Calculated Summary						
EQ Type	EQ ID	Size	Quantity	Leakage Class	Leakage Factor	EQ CFM
Allowable Equipment Air Leakage (L_E)						0

Appendix B

- **Mechanical Access Door**
- Test Pressure = 6 in. w.g.
- Leakage Factor (F_A) = 5

B.4 MECHANICAL ACCESS DOORS

The following formula used with leakage test data is used to develop Mechanical Access Door Allowable Leakage. Refer to Section 4.5.2.c:

$F_A = C_{LA} P^N$

$L_A = Q_A F_A$

Where:

F_A is the leakage from a single accessory
C_{LA} is accessory leakage class
P is test pressure in. wg
^{N} is an exponent (.50 for ductwork accessories)
Q_A is quantity of the accessory
L_A is the amount of allowed leakage for a specific accessory

Mechanical Access Door Allowable Duct Leakage CFM Each								
1/4" wg	1/2" wg	1" wg	1 1/2" wg	2" wg	3" wg	4" wg	6" wg	10" wg
1	1	2	2	3	3	4	5	6

TABLE B–10 MECHANICAL ACCESS DOOR ALLOWABLE LEAKAGE

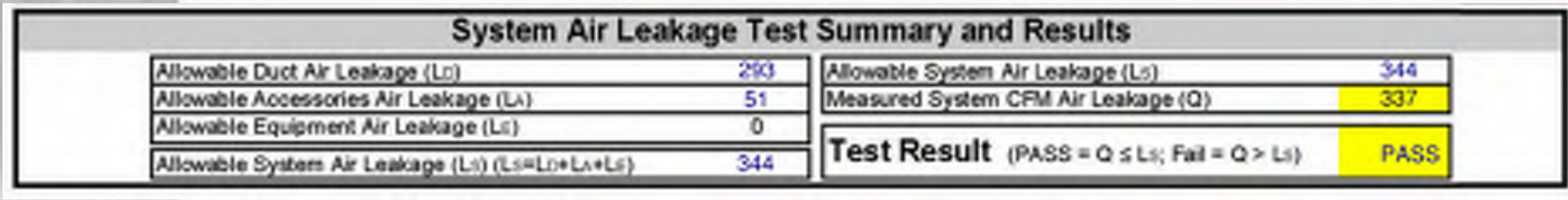
Accessories and Equipment Calculated Allowable Air Leakage Summary

Accessories (ACC) Allowable Air Leakage Calculated Summary						
Acc Type	Acc ID	Size	Quantity	Leakage Class	Leakage Factor	ACC CFM
T. U.	VB08	12"	1	NA	27	27
V. Damper	NA	NA	1	3	7	7
F/S Damper	NA	NA	1	5	12	12
MAD	NA	NA	1	1	5	5
Allowable Accessories Air Leakage (L_A)						51

Equipment (EQ) Allowable Air Leakage Calculated Summary						
EQ Type	EQ ID	Size	Quantity	Leakage Class	Leakage Factor	EQ CFM
Allowable Equipment Air Leakage (L_E)						0

Testing Forms

- Summary and Test Results Section



System Air Leakage Test Summary and Results

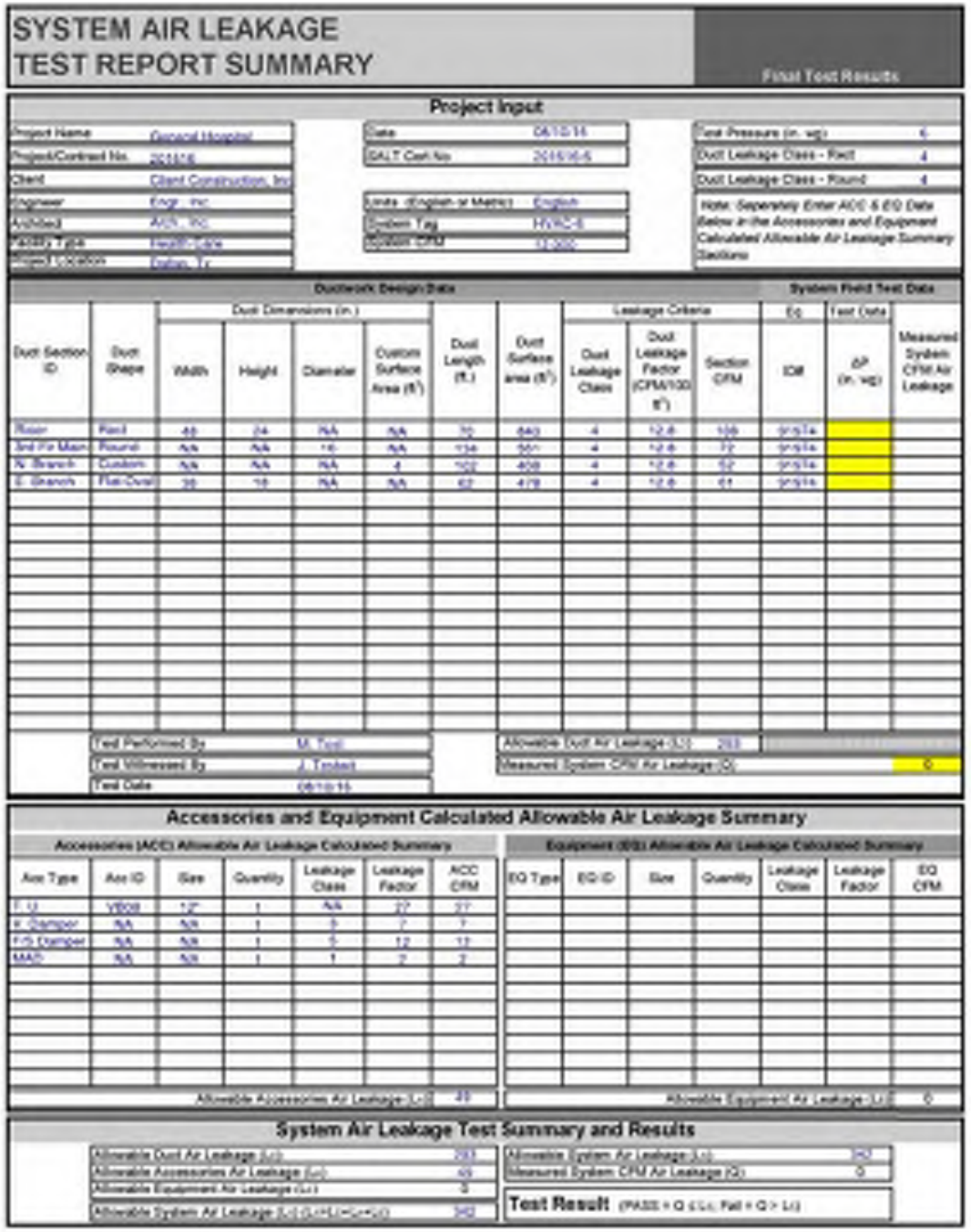
Allowable Duct Air Leakage (L_D)	293	Allowable System Air Leakage (L_S)	344
Allowable Accessories Air Leakage (L_A)	51	Measured System CFM Air Leakage (Q)	337
Allowable Equipment Air Leakage (L_E)	0	**Test Result** (PASS = $Q \leq L_S$; Fail = $Q > L_S$)	PASS
Allowable System Air Leakage (L_S) ($L_S = L_D + L_A + L_E$)	344		

- Allowable System Air Leakage = 344 CFM
- Measured System Air Leakage = 337 CFM
- Test Result = PASS

Testing Forms

Example: Completed Test Form

- Completely Document the Following:
  - Test Pressure
  - Components / Systems Tested
  - Allowable System Leakage
    - Calculated Leakage (SALT Method)
    - Defined Leakage (as per E.O.R.)
  - Pass / Fail Clearly Established



SYSTEM AIR LEAKAGE
TEST REPORT SUMMARY

Final Test Results

Project Input

Project Name	General Hospital	Date	08/10/15	Test Pressure (in. wg)	6
Project/Contract No.	2015-6	SALT Cert No.	2015-06-6	Duct Leakage Class - Rect	4
Client	Client Construction, Inc			Duct Leakage Class - Round	4
Engineer	Engr. Inc	Units (English or Metric)	English	Note: Separately Enter A(c) & E(q) Data Below in the Accessories and Equipment Calculated Allowable Air Leakage Summary Sections	
Architect	Arch. Inc	System Type	HVAC-6		
Facility Type	Health Care	System CFM	12,000		
Project Location	Dallas, Tx				

Ductwork Design Data | System Field Test Data

Duct Section ID	Duct Shape	Duct Dimensions (in.) Width	Height	Diameter	Custom Surface Area (ft²)	Duct Length (ft.)	Duct Surface area (ft²)	Leakage Criteria Duct Leakage Class	Duct Leakage Factor (CFM/100 ft²)	Section CFM	Eq ID#	Test Data ΔP (in. wg)	Measured System CFM Air Leakage
Riser	Rect	48	24	NA	NA	70	840	4	12.8	106	3/15/14		
3rd Flr Main	Round	NA	NA	16	NA	134	561	4	12.8	72	3/15/14		
N. Branch	Custom	NA	NA	NA	4	102	408	4	12.8	52	3/15/14		
E. Branch	Flat Oval	30	10	NA	NA	67	478	4	12.8	61	3/15/14		

Test Performed By: M. Test
Test Witnessed By: J. Tester
Test Date: 08/10/15

Allowable Duct Air Leakage (L1): 283
Measured System CFM Air Leakage (Q): 0

Accessories and Equipment Calculated Allowable Air Leakage Summary

Accessories (ACC) Allowable Air Leakage Calculated Summary

Acc Type	Acc ID	Size	Quantity	Leakage Class	Leakage Factor	ACC CFM
E. U.	VB08	12"	1	NA	22	22
# Damper	NA	NA	1	5	7	7
F/S Damper	NA	NA	1	5	12	12
MAT	NA	NA	1	1	2	2

Allowable Accessories Air Leakage (L2): 43

Equipment (EQ) Allowable Air Leakage Calculated Summary

EQ Type	EQ ID	Size	Quantity	Leakage Class	Leakage Factor	EQ CFM

Allowable Equipment Air Leakage (L3): 0

System Air Leakage Test Summary and Results

Allowable Duct Air Leakage (L1)	283	Allowable System Air Leakage (L)	347
Allowable Accessories Air Leakage (L2)	43	Measured System CFM Air Leakage (Q)	0
Allowable Equipment Air Leakage (L3)	0	Test Result (PASS = Q ≤ L; Fail = Q > L)	
Allowable System Air Leakage (L) = (L1+L2+L3)	347		

FIGURE 6–1 SYSTEM AIR LEAKAGE TEST REPORT SUMMARY

Testing Forms

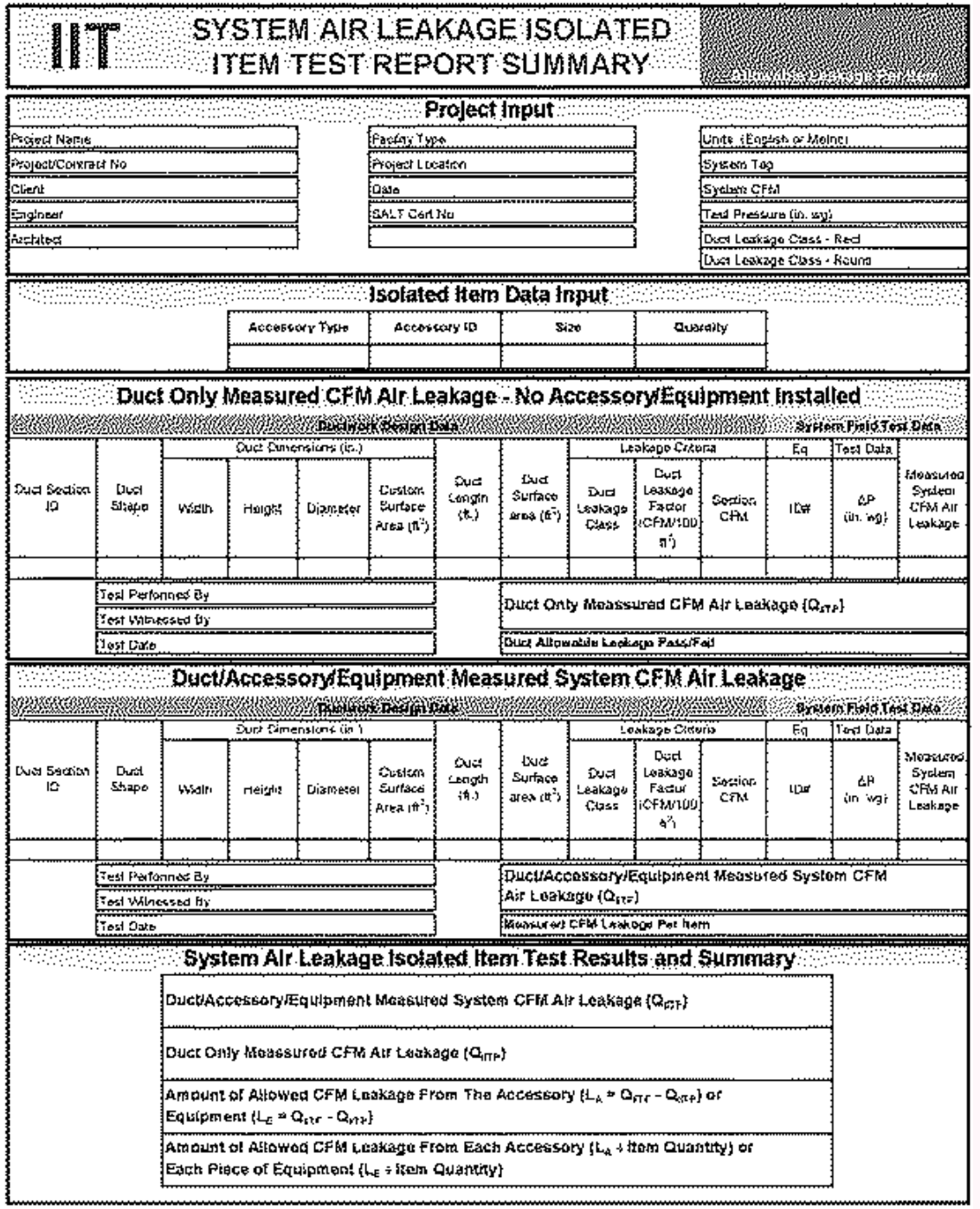
What if the Leakage Values are not Published?

- We can use the ISOLATED ITEM TEST
  - Qualify the leakage value of an accessory or in-line piece of Equipment!

Testing Forms

IIT: Isolated Item Test Report

- Figure 6-3 (Page 6.7)
- Allows for field testing of:
  - Duct Section
  - Accessories Section
  - Equipment Section



IIT SYSTEM AIR LEAKAGE ISOLATED ITEM TEST REPORT SUMMARY

Project Input

Project Name | Facility Type | Units (English or Metric)
Project/Contract No | Project Location | System Tag
Client | Date | System CFM
Engineer | SALT Cert No | Test Pressure (in. wg)
Architect | | Duct Leakage Class - Rect
| | Duct Leakage Class - Round

Isolated Item Data Input

Accessory Type	Accessory ID	Size	Quantity

Duct Only Measured CFM Air Leakage - No Accessory/Equipment Installed

Ductwork Design Data | System Field Test Data

Duct Section ID	Duct Shape	Duct Dimensions (in.) Width	Height	Diameter	Custom Surface Area (ft^2)	Duct Length (ft.)	Duct Surface area (ft^2)	Leakage Criteria Duct Leakage Class	Duct Leakage Factor (CFM/100 ft^2)	Section CFM	Eq ID#	Test Data ΔP (in. wg)	Measured System CFM Air Leakage

Test Performed By
Test Witnessed By
Test Date

Duct Only Measured CFM Air Leakage (Q_{ITP})
Duct Allowable Leakage Pass/Fail

Duct/Accessory/Equipment Measured System CFM Air Leakage

Ductwork Design Data | System Field Test Data

Duct Section ID	Duct Shape	Duct Dimensions (in.) Width	Height	Diameter	Custom Surface Area (ft^2)	Duct Length (ft.)	Duct Surface area (ft^2)	Leakage Criteria Duct Leakage Class	Duct Leakage Factor (CFM/100 ft^2)	Section CFM	Eq ID#	Test Data ΔP (in. wg)	Measured System CFM Air Leakage

Test Performed By
Test Witnessed By
Test Date

Duct/Accessory/Equipment Measured System CFM Air Leakage (Q_{ITF})
Measured CFM Leakage Per Item

System Air Leakage Isolated Item Test Results and Summary

Duct/Accessory/Equipment Measured System CFM Air Leakage (Q_{ITF})
Duct Only Measured CFM Air Leakage (Q_{ITP})
Amount of Allowed CFM Leakage From The Accessory ($L_A = Q_{ITF} - Q_{ITP}$) or Equipment ($L_E = Q_{ITF} - Q_{ITP}$)
Amount of Allowed CFM Leakage From Each Accessory ($L_A \div$ Item Quantity) or Each Piece of Equipment ($L_E \div$ Item Quantity)

Testing Forms: ITT

ITT: Isolated Item Test Report

1. Project Information Section

IIT — **SYSTEM AIR LEAKAGE ISOLATED ITEM TEST REPORT SUMMARY**

6 CFM — Allowable Leakage Per Item

Project Input

Project Name	Ambulatory Care Center	Facility Type	Health Care	Units (English or Metric)	English
Project/Contract No.	201616	Project Location	Raleigh, NC	System Tag	AHU-4
Client	Client Construction, Inc.	Date	05/22/17	System CFM	5,000
Engineer	Engr, Inc.	SALT Cert No	201722-5	Test Pressure (in. wg)	2
Architect	Arch, Inc.			Duct Leakage Class - Rect	4
				Duct Leakage Class - Round	4

Testing Forms: ITT

ITT: Isolated Item Test Report

2. Identify Isolated Item

Isolated Item Data Input

Accessory Type	Accessory ID	Size	Quantity
Fire/Smoke Damper	F/S Dpr	24" x 14"	1

Testing Forms: ITT

ITT: Isolated Item Test Report

3. Test the Duct Section (only)
   - Accessory is not installed at this time

Duct Only Measured CFM Air Leakage - No Accessory/Equipment Installed

Ductwork Design Data												System Field Test Data		
Duct Section ID	Duct Shape	Duct Dimensions (in.)				Duct Length (ft.)	Duct Surface area (ft^2)	Leakage Criteria			Eq	Test Data	Measured System CFM Air Leakage
		Width	Height	Diameter	Custom Surface Area (ft^2)			Duct Leakage Class	Duct Leakage Factor (CFM/100 ft^2)	Section CFM	ID#	ΔP (in. wg)	
11' Test Sec	Rect	24	14	NA	NA	11	70	4	6.3	4	91974	0.10	3

Test Performed By	M. Test
Test Witnessed By	J. Testwit
Test Date	05/24/17

Duct Only Meassured CFM Air Leakage (Q_{IITP}) 3

Duct Allowable Leakage Pass/Fail PASS

Testing Forms: ITT

ITT: Isolated Item Test Report

4. Test the Duct Section with Accessory Installed
   - Record the Leakage Value (9 cfm)

Duct/Accessory/Equipment Measured System CFM Air Leakage

Ductwork Design Data													System Field Test Data	
Duct Section ID	Duct Shape	Duct Dimensions (in.)				Duct Length (ft.)	Duct Surface area (ft^2)	Leakage Criteria			Eq	Test Data		Measured System CFM Air Leakage
		Width	Height	Diameter	Custom Surface Area (ft^2)			Duct Leakage Class	Duct Leakage Factor (CFM/100 ft^2)	Section CFM	ID#	ΔP (in. wg)		
11' Test Sec	Rect	24	14	NA	NA	11	70	4	6.3	4	91974	0.10		9

Test Performed By	M. Test
Test Witnessed By	J. Testwit
Test Date	05/24/17

Duct/Accessory/Equipment Measured System CFM Air Leakage (Q_{IITF})	9
Measured CFM Leakage Per Item	9

Testing Forms: ITT

ITT: Isolated Item Test Report

4. Complete the Test Results Summary
   - Allowable Leakage per Accessory = 6 cfm

System Air Leakage Isolated Item Test Results and Summary	
Duct/Accessory/Equipment Measured System CFM Air Leakage (Q_{IITF})	9
Duct Only Meassured CFM Air Leakage (Q_{IITP})	3
Amount of Allowed CFM Leakage From The Accessory ($L_A = Q_{IITF} - Q_{IITP}$) or Equipment ($L_E = Q_{IITF} - Q_{IITP}$)	6
Amount of Allowed CFM Leakage From each Accessory ($L_A \div$ Item Quantity) or Each Piece of Equipment ($L_E \div$ Item Quantity)	**6**

Connecticut ASHRAE

Tech Session

Thank you!

Questions? Reach out to me at:

www.smacna.org

wfarrell@smacna.org

10-2-2024