Agenda

• Need for duct leakage testing
• Duct leakage testing standards and regulations
• Performing duct leakage testing
Why Test Ducts for Leakage?

• Conserve energy
  – 10-30% of heated/cooled air lost through ductwork
  – Leaky supply ducts don’t delivery air where needed
  – Leaky return ducts add load
Why Test Ducts for Leakage?

• Indoor Air Quality
  – Leaky returns can pull in air from uncontrolled spaces, causing
    • Humidity problems
    • Contaminants
System Leakage

• IAQ, Comfort, Energy issues caused by leakage from HVAC System
• System Leakage = Duct Leakage + Equipment Leakage + Accessory Leakage
• Scope of presentation = Duct leakage
  – Does not include:
    • Leakage through Equipment (See ASHRAE 193)
    • Leakage through Accessories
  – Commercial & industrial systems
    • Similar concepts for residential
Why Test Ducts for Leakage?

• Requirements
  – US
    • SMACNA HVAC Air Duct Leakage Test manual, First edition, 1985
    • ASHRAE 90.1 (Proposed)
    • Project specifications
    • California Title 24 → residential testing required if ahu/furnace in garage or ducts in non-conditioned space (attic)
  – Europe
    • BS EN 12237:2003 – Circular Ductwork
    • BS EN 1507:2006 – Rectangular Ductwork
    • DW/143 (HVAC—A practical guide to Ductwork leakage testing)
    • Eurovent 2/2 (Air leakage rate in sheet metal air distribution systems)
Where Does Duct Leakage Occur?

- Transverse Joint
  - Duct-to-duct, -branch, -tap, etc.
- Longitudinal Seam
  - Joining of 2 edges in direction of airflow
- Penetration
  - Rod, wire, tubing, etc.
- Sealing not required:
  - Spiral seams
  - Screws & fasteners
  - Damper rods
Where Does Duct Leakage Occur?

• Higher-pressure ductwork
  – ASHRAE 90.1 recommends only testing ductwork rated >3 in H₂O
  – Don’t test flex duct
How to Test Duct Leakage (Basic)

• Identify ductwork section to be tested
  – Calculated surface area
• Seal ductwork
• Pressurize ductwork to specified level
• Measure flow required to maintain duct pressure
• Compare to standards
Duct Leakage Measurements

• % of Flow requirements
  – Problem: Disregards size of ductwork & static pressure
  – i.e. 1% of flow on 3900 cfm system = 39 cfm.
    If 1300 ft$^2$ duct area = 3 cfm leakage / 100 ft$^2$
    300 ft$^2$ duct area = 13 cfm leakage / 100 ft$^2$

• Test pressure requirements
  – Problem: Test pressure higher than duct design
  – i.e. testing system designed for 2 in H$_2$O operation at 10 in H$_2$O

• Need to consider
  – Surface area of ductwork
    • Type of ductwork (round, rectangular)
  – Static pressure
# US Duct Leakage Testing Requirements - (SMACNA)

<table>
<thead>
<tr>
<th>Duct Class</th>
<th>½-, 1-, 2-inwg</th>
<th>3-inwg</th>
<th>4-, 6-, 10-inwg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal Class</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Sealing Applicable</td>
<td>Transverse Joints Only</td>
<td>Transverse Joints and Seams</td>
<td>Joints, Seams and All Wall Penetrations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leakage Class ($C_L$) – CFM Leakage per 100 ft$^2$ @ 1 in H$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular Metal</td>
</tr>
<tr>
<td>24</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>Round Metal</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

\[ F = C_L \times P^{0.65} \]

- $F$ = Max Leakage (cfm/100 ft$^2$)
- $C_L$ = Leakage Class (from table above)
- $P$ = Pressure (in H$_2$O)
Prior to Field Testing
Prior to Field Testing

1) Duct System Designer:

Include on Design/Contract Drawing:

• Specify Duct Pressure Classification
US Duct Leakage Testing Requirements - (SMACNA)

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</tbody>
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Leakage Class ($C_L$) – CFM Leakage per 100 ft$^2$ @ 1 in H$_2$O

| Rectangular Metal | 24   | 12   | 6    |
| Round Metal       | 12   | 6    | 3    |

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

- $F = \text{Max Leakage (cfm/100 ft}^2)$
- $C_L = \text{Leakage Class (from table above)}$
- $P = \text{Pressure (in H}_2\text{O)}$
Duct Leakage Equation

\[ F = C_L P^{0.65} \]

Where

- \( F \) = Leakage [CFM] / 100 ft\(^2\)
- \( C_L \) = Duct Leakage Classification
- \( P \) = Duct Static Pressure ["w.g."
Prior to Field Testing

1) Duct System Designer:
   Include on Design/Contract Drawing:
   - Test (or not) as installed? Depends on design intent/requirements
   - If Test: Specify on Dwgs
     - Portion of ductwork, or whole system?
     - Positive Pressure? Negative?
     - Provide method details
Prior to Field Testing

Quote from *HVAC AIR DUCT LEAKAGE TEST MANUAL* (SMACNA):

“WHERE NO SPECIFIC DUCT PRESSURE CLASS DESIGNATIONS ARE PROVIDED BY THE DESIGNER THE 1” WATER GAGE PRESSURE CLASS IS THE BASIS OF COMPLIANCE…”
Prior to Field Testing

… EXCEPT WHEN THE DUCT IS VARIABLE VOLUME: ALL VARIABLE VOLUME DUCT UPSTREAM OF VAV BOXES HAS A 2” W.G. BASIS OF COMPLIANCE WHEN THE DESIGNER DOES NOT GIVE A PRESSURE CLASS.”

– from SMACNA HVAC AIR DUCT LEAKAGE TEST MANUAL, 1985
Prior to Field Testing

2) Testing Agency: Prepare paperwork

- Test plan
- Test report form
Prior to Field Testing

3) Testing Agency: Prepare the site
   • Plan/Coordinate with construction/installation contractors
   • Blanking materials
   • Equipment
     • Select according to Test Requirements
     • Consider
       • System Flowrate
       • Leakage Classification
       • Flow Capacity of Test System
Prior to Field Testing

• Equipment Details:
  – Must use instruments that have been calibrated within the past 12 months
  – Calibration certificates traceable to NIST
  – Consider Test System capabilities:
    • Ability to Log data and download with Time/Date stamp vs. using liquid-inclined and U-tube manometers
Prior to Field Testing

• Contingency planning

  (Designer: Put plans in contract drawing/specs)

  – If duct leak test FAILS – then what?

  REMEDIATE!
Prior to Field Testing

• REMEDIATION Plan
  – Seal the leaks
  – Wait for seals to cure
  – Re-test
    • Re-test failed section only?
    • Does section failure trigger need to test more sections?

SPECIFY!
Test Procedure

1) Select Duct Section for Testing

2) Measure and Calculate Duct Surface Area

3) Seal All Openings (except one)
Fig. 1  Hints on Ductwork Leakage Testing

The dimensions on this ductwork are used in an example on page 7

SEQUENCE OF TEST
1. Prepare test sheet.
2. Connect and adjust test rig to correct pressure.
3. Read off leakage rate.
4. Repeat if necessary (a new test run).
5. Maintain test for 15 minutes.
6. Switch off test rig to zero.
7. Record test pressure and check readings.
8. Record details on test sheet and obtain signature.

WARNING
Table data not be used pressures system under test.

HOW TO FIND LEAKS
1. Leak — particularly at联线, overs opened openings
2. Loops — with leak detection tools
3. Vent — running your hand (particularly at vents)
4. Smoke — smoke can help locate leaks
5. Smoke Pellets — smoke (obtain permission for use)

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Test Apparatus

Duct Leakage Test System consists of:

1) Blower with speed control (VFD) to generate range of pressure/flow
2) Flow measuring devices
   - Flow Grid/Flow Station (High Flow)
   - Orifice Plate (Low Flow)
3) Pressure instruments (manometers)
4) Accessories to attach to duct system
5) Optional item (smoke generator)
Test System: Considerations

• Maximize: Flow Range
  – Limits duct section size/Leakage Rate

• Maximize: Pressure Range
  – High Pressure Blower to cover duct classes
    • ½” to 10” w.g.

• Maximize: Instrument Measurement Accuracy
  – Flow: 2.5% of reading
  – Pressure: 1% of reading
Test System Considerations

• Instrumentation:
  – Traceable to National Standards (NIST)
  – Logging capability – SIMPLIFY!
    • Time/Date Stamp on each data set
    • Calculates Flows
    • Calculates Leakage rate based on duct ft$^2$ input
    • Indicates PASS/FAIL status according to selectable defined leakage classifications
    • Report generation and validation
28.71 in. Hg bp

Test 009
Zero Press
Display Setup
Settings
Flow Setup
VOC Setup
Actual/Std Setup
Data Logging
Zero CO
Applications
Calibration
Discover Printer
APPLICATIONS

Draft Rate
Heatflow
Turbulence
% Outside Air
Leakage Test
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Area</td>
<td>1123 ft²</td>
</tr>
<tr>
<td>Static Press</td>
<td>0.993 in. H₂O</td>
</tr>
<tr>
<td>Flow Device</td>
<td>Flow Grid</td>
</tr>
<tr>
<td>Tightness Class</td>
<td>B</td>
</tr>
<tr>
<td>Test Length</td>
<td></td>
</tr>
<tr>
<td>Run Test</td>
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</table>
TEST LENGTH

05:00
Min:Sec
<table>
<thead>
<tr>
<th>Test Description</th>
<th>Result</th>
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<tbody>
<tr>
<td>Surface Area</td>
<td>1123 ft²</td>
</tr>
<tr>
<td>Static Press</td>
<td>0.993 in. H₂O</td>
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<tr>
<td>Flow Device</td>
<td>Flow Grid</td>
</tr>
<tr>
<td>Tightness Class Class B</td>
<td></td>
</tr>
<tr>
<td>Test Length</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Leak Factor</td>
<td>0.08085 CFM/ft²</td>
</tr>
<tr>
<td>Leak Limit</td>
<td>0.0637 CFM/ft²</td>
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<tr>
<td>Leak Rate</td>
<td>02.80 CFM</td>
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<tr>
<td>Status</td>
<td>High</td>
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<tr>
<td>Flow Device</td>
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<tr>
<td>Baro Press</td>
<td>28.65 in.Hg</td>
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<tr>
<td>Temperature</td>
<td>67.8 °F</td>
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<tr>
<td>Time</td>
<td>0:05</td>
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<tr>
<td>Standard</td>
<td>Test 009 Sample</td>
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<td>Parameter</td>
<td>Value</td>
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<td>--------------------</td>
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<tr>
<td>Leak Factor</td>
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<td>Leak Limit</td>
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<tr>
<td>Leak Rate</td>
<td>90.95 CFM</td>
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<td>Status</td>
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<td>Flow Device</td>
<td>Flow Grid</td>
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<tr>
<td>Baro Press</td>
<td>28.65 in. Hg</td>
</tr>
<tr>
<td>Temperature</td>
<td>67.8°F</td>
</tr>
<tr>
<td>Time</td>
<td>0:00</td>
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<tr>
<td>Standard</td>
<td>Test 009</td>
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<td>Sample</td>
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<tr>
<td>Test Done</td>
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<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Leak Factor</td>
<td>0.06218 CFM/ft²</td>
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<tr>
<td>Leak Limit</td>
<td>0.0637 CFM/ft²</td>
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<tr>
<td>Leak Rate</td>
<td>69.83 CFM</td>
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<tr>
<td>Status</td>
<td>Pass</td>
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<td>Flow Device</td>
<td>Flow Grid</td>
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<tr>
<td>Baro Press</td>
<td>28.70 in.Hg</td>
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<tr>
<td>Temperature</td>
<td>63.9°F</td>
</tr>
<tr>
<td>Time</td>
<td>0:00</td>
</tr>
<tr>
<td>Standard</td>
<td>Test 009 Sample 0</td>
</tr>
<tr>
<td>Test Done</td>
<td></td>
</tr>
</tbody>
</table>

SAVE  PRINT
Summary

• Leaky ductwork is costly

• There are Standards and Test Procedures

• Designer: Be Specific with specs and instructions

• Choose the right Test Equipment
Contacts

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  • Ken.helfers@tsi.com
  • 502-897-0945

• Siva Iyer, TSI Inc.
  • siva.iyer@tsi.com
  • 651-765-3721
# European Duct Leakage Requirements - Round Ducts

<table>
<thead>
<tr>
<th>Duct Pressure Class</th>
<th>Static Pressure Limit</th>
<th>Maximum Air Velocity</th>
<th>Air leakage limits l/s/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive Pa</td>
<td>Negative Pa</td>
<td>m/s</td>
</tr>
<tr>
<td>Low pressure – Class A</td>
<td>500</td>
<td>500</td>
<td>10</td>
</tr>
<tr>
<td>Medium pressure – Class B</td>
<td>1000</td>
<td>750</td>
<td>20</td>
</tr>
<tr>
<td>High pressure – Class C</td>
<td>2000</td>
<td>750</td>
<td>40</td>
</tr>
</tbody>
</table>

- \(p_t = \text{test pressure}\)
## European Duct Leakage Requirements - Rectangular Ducts

<table>
<thead>
<tr>
<th>Air Tightness Class</th>
<th>Static Pressure Limit ($p_s$) Pa</th>
<th>Positive at pressure class</th>
<th>Air Leakage Limit l/s/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Low pressure – Class A</td>
<td>500</td>
<td>400</td>
<td>NA</td>
</tr>
<tr>
<td>Medium pressure – Class B</td>
<td>750</td>
<td>400</td>
<td>1000</td>
</tr>
<tr>
<td>High pressure – Class C</td>
<td>750</td>
<td>400</td>
<td>1000</td>
</tr>
</tbody>
</table>

- $P_t =$ test pressure
Comparison of SMACNA & EU Leakage Requirements

![Comparison of SMACNA & EU Leakage Requirements](image_url)
## Comparison

<table>
<thead>
<tr>
<th>Standard / Actual Conversions</th>
<th>EU Standards</th>
<th>SMACNA Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Required</td>
<td>Suggested if:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Air Temp &lt;40°F or &gt;100°F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Elevation &gt;1500 feet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Duct static &lt;-20 in H$_2$O or &gt;+20 in H$_2$O</td>
</tr>
</tbody>
</table>
# Comparison

<table>
<thead>
<tr>
<th>Report Requirements</th>
<th>EU Standards</th>
<th>SMACNA Standard</th>
</tr>
</thead>
</table>
| Specified in Standards | • Site details  
  • Date  
  • Location  
  • Test equipment  
  • Personnel & witnesses  
  • Ductwork installer & manufacturer  
  • Duct design operating pressure  
  • Required Air Tightness Class | Defers to project specifications. Suggests:  
• Site Details  
  • Date  
  • Location  
  • Personnel & witnesses  
  • Duct section tested |
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>EU Standards</th>
<th>SMACNA Standard</th>
</tr>
</thead>
</table>
| **Report Requirements** | Specified in Standards  
• Measurements  
  • Duct surface area  
  • Test pressure  
  • Leakage rate  
  • Pressurizing time  
  • Calculated  
    • Leakage factor  
    • Air Leakage Limit  
    • Pass/fail result | Defers to project specifications. Suggests:  
• Measurements  
  • Duct surface area  
  • Test pressure  
  • Leakage rate  
  • Calculated  
  • Max Air Leakage allowed  
  • Pass/fail result |