Building Air Leakage

• **What is Building Envelope Testing?**
  - Whole Building Pressure Testing
  - Zone or Component Leak Testing

• **What it is Not**
  - Material or Component Testing
  - Factory material testing
• What does Building Pressure Testing Do?
  • Tests the effectiveness of Air Barriers
  • Tests for the presence of openings
  • Directly tied to building energy usage
  • Directly tied to building comfort
Building Air Leakage

Required Knowledge

- **Envelope Construction**
- **Walls**
  - Rainwater Control
  - Air Control Layer
  - Vapor Control Layer
  - Thermal Control Layer

Diagram:
- Exterior Cladding
- Drainage Channel
- Air & Vapor Barrier
- Insulation
- Exterior Wall Board
- Wall Structure
- Interior Wall Board
Building Air Leakage

Required Knowledge

- **Envelope Construction**
  - Roofs
    - Water leakage
    - Air Barrier
    - Flashing
    - Expansion Joints
Building Air Leakage

Required Knowledge

- Envelope Construction
- Doors and Windows
  - Thermal Transfer
  - Water Channel & Leakage
  - Air Leakage
  - Expansion and Contraction
Building Air Leakage

- Normal Leakage Ranges
  - Non tested building
    Not unusual to see 0.1 to 0.15 CFM / Square Foot
    For a 100,000 SF building this could equal $25,000 to $80,000 annual added utility costs
  - Tested building
    Tight building could be as low as .05 – 0.75 CFM / Square Foot
### Design Leakage Rates

### Guide Standards

**Table 7-1: Common Specified Air Leakage Rates**

<table>
<thead>
<tr>
<th>National Standards</th>
<th>Lowest Leakage Rate</th>
<th>Highest Leakage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>0.66 L/s / m² (0.13 cfm / ft²)</td>
<td>1.68 L/s / m² (0.33 cfm / ft²)</td>
</tr>
<tr>
<td>Canada</td>
<td>0.66 L/s / m² (0.13 cfm / ft²)</td>
<td>1.68 L/s / m² (0.33 cfm / ft²)</td>
</tr>
<tr>
<td>Industry</td>
<td>0.48 L/s / m² (0.10 cfm / ft²)</td>
<td>1.92 L/s / m² (0.40 cfm / ft²)</td>
</tr>
<tr>
<td>Corps of Engineers</td>
<td></td>
<td>1.27 L/s / m² (0.25 cfm / ft²)</td>
</tr>
<tr>
<td>Corps of Engineers (2012 Proposed)</td>
<td></td>
<td>0.76 L/s / m² (0.15 cfm / ft²)</td>
</tr>
<tr>
<td>Dept. of the Navy</td>
<td></td>
<td>1.27 L/s / m² (0.25 cfm / ft²)</td>
</tr>
<tr>
<td>Dept. of the Air Force</td>
<td></td>
<td>2.00 L/s / m² (0.40 cfm / ft²)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Standards</th>
<th>Lowest Leakage Rate</th>
<th>Highest Leakage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Buildings</td>
<td>0.48 L/s / m² (0.10 cfm / ft²)</td>
<td>1.20 L/s / m² (0.25 cfm / ft²)</td>
</tr>
<tr>
<td>Warehouses</td>
<td>0.62 L/s / m² (0.13 cfm / ft²)</td>
<td>1.20 L/s / m² (0.25 cfm / ft²)</td>
</tr>
<tr>
<td>Repair Shops</td>
<td>1.20 L/s / m² (0.25 cfm / ft²)</td>
<td>1.92 L/s / m² (0.40 cfm / ft²)</td>
</tr>
<tr>
<td>Hospitals</td>
<td>0.48 L/s / m² (0.10 cfm / ft²)</td>
<td>1.20 L/s / m² (0.25 cfm / ft²)</td>
</tr>
<tr>
<td>Housing Units</td>
<td></td>
<td>0.77 L/s / m² (0.16 cfm / ft²)</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>0.51 L/s / m² (0.10 cfm / ft²)</td>
<td>3.0 L/s / m² (0.60 cfm / ft²)</td>
</tr>
</tbody>
</table>
Design Leakage Rates

- **ACE Standard**
  - 0.25 CFM @ 75PA / SF Barrier

- **NEBB Standard**
  - 0.40 – 0.16 CFM @ 75PA / SF Barrier
Building Air Leakage

- **Air Barrier SF Calculation**
  - Area of bottom Floor
  - Area of top Floor Ceiling air barrier
  - Area of the wall air barrier
  - Total Air Barrier $\times$ Leakage Rate = Total allowable leakage
Building Air Leakage

- Design Leakage Rates
  - Based upon building type
    - High Mass = Low Leakage rates
    - Low Mass = High Leakage rates

- Specifying a Leakage Rate
  - Rate between 0.40 to 0.16 CFM / SF of Barrier

- Specifying a Test Pressure
  - Either 75PA or 50PA [0.3” or 0.2”] Normal operating rate [0.03” to 0.02”]
• **Limitations of air Leakage Tests**

• **Whole Building Tests**
  
  • Size < 150,000 SF (Rate =<0.25)
  
  • Temperature x Height <1180 Degree Feet
    (30 degrees x 36’ = 1080)
  
  • Wind < 6 MPH or gusting 4 MPH over steady state wind speed
  
  • Unoccupied only
Building Air Leakage

• Limitations of air Leakage Tests

• Whole Building Tests
  • Blower doors 1-20 fans maximum
  • Installed on leeward side of building
  • Controlled as one unit
**Building Air Leakage**

- **Limitations of air Leakage Tests**
  - **Component Section Tests**
    - Test Zones or Areas
    - Test wall / window sections
    - No total leakage rate

Window Assembly Pressure Test

Window

Window Frame

Test Frame Cover

Test Gauges

Pressure Fan & Flow Grid or Orifice

Structural Test Frame

Test Membrane Seal

0.025

Less Than

0.09 CFM / Sq Ft

Window Assembly 
Pressure Test
Limitations of air Leakage Tests

Using the HVAC System

- Accuracy of test is much less than blower door
- Very difficult to do both pressurization and depressurization tests
- System must be designed specifically to be used to perform pressure testing
  - Measurement devices and locations
  - System capacity
• 100,000 SF Building = 70,000 CFM to 100,000 CFM
• Test Rate both + and - = 65,000 CMF @ 0.25 to 108,000 CFM @ 0.40
• SF and RF must be sized for building pressure testing Flow and Pressure
• Accurate Flow and Pressure measurement stations
Building Air Leakage

- Testing Standards
  - ASTM E779
  - ASTM E1827
  - CIBSE TM23
  - USACE
  - NEBB
Building Air Leakage

- **Building Set Up**
- **Isolating Area to be Tested**
- **Adjacent Areas**
- **What to seal and what to leave open**

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Envelope Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust fans with back draft dampers</td>
<td>Open</td>
</tr>
<tr>
<td>Supply fans with back draft dampers</td>
<td>Open</td>
</tr>
<tr>
<td>Furnace room door for furnace outside test zone</td>
<td>Closed</td>
</tr>
<tr>
<td>Combustion air intake dampers for boilers</td>
<td>Closed</td>
</tr>
<tr>
<td>Outside air intake damper for Air Handling Unit inside test zone</td>
<td>Closed</td>
</tr>
<tr>
<td>Outside air intake for Air Handling Unit inside test zone without damper</td>
<td>Sealed</td>
</tr>
<tr>
<td>Exhaust, Air Handling Units, Make-up Air Units, Energy Recovery Units, Supply fans, Furnaces, Fan Coil Units, Boilers, Gas Hot Water Heaters, All equipment requiring combustion air (including kitchen equipment, HVAC, etc.)</td>
<td>Off</td>
</tr>
<tr>
<td>Fan inlet grilles with motorized damper</td>
<td>Closed</td>
</tr>
<tr>
<td>Fan inlet grilles without motorized damper</td>
<td>Sealed</td>
</tr>
<tr>
<td>Ventilators designed for continuous use</td>
<td>Sealed</td>
</tr>
<tr>
<td>Supply and exhaust ventilator dampers</td>
<td>Sealed</td>
</tr>
<tr>
<td>Clothes dryer</td>
<td>Off</td>
</tr>
<tr>
<td>If clothes dryer is connected to the dryer vent</td>
<td>No preparation</td>
</tr>
<tr>
<td>Ventilated combustion appliance</td>
<td>Off</td>
</tr>
<tr>
<td>Ventilation to other zones</td>
<td>Off</td>
</tr>
<tr>
<td>Windows</td>
<td>Closed and Latched</td>
</tr>
<tr>
<td>Exterior doors</td>
<td>Closed and Latched</td>
</tr>
<tr>
<td>Window air conditioners</td>
<td>Sealed</td>
</tr>
<tr>
<td>Through the wall air conditioners outside air vent</td>
<td>Sealed</td>
</tr>
<tr>
<td>Openings leading to outside the test zone</td>
<td>Closed</td>
</tr>
<tr>
<td>All HVAC ducts going from inside the test zone to outside the test zone and back into the test zone</td>
<td>Sealed</td>
</tr>
<tr>
<td>All electrical conduits going from inside the test zone to outside the test zone and back into the test zone</td>
<td>Sealed</td>
</tr>
<tr>
<td>Openings within the test zone</td>
<td>Open</td>
</tr>
<tr>
<td>Floor drains and plumbing traps</td>
<td>Filled</td>
</tr>
<tr>
<td>Elevator pressure relief openings</td>
<td>Closed</td>
</tr>
<tr>
<td>Elevator Doors</td>
<td>Closed</td>
</tr>
<tr>
<td>Elevator Door Frame spacing between the elevator door and frame if the elevator connects an area outside the air barrier</td>
<td>Sealed</td>
</tr>
<tr>
<td>Elevator Door Frame spacing between the elevator door and frame if the elevator connects an area within the air barrier</td>
<td>Open</td>
</tr>
<tr>
<td>Rooms with Exterior, non-ducted louvers (interior doors)</td>
<td>Closed</td>
</tr>
<tr>
<td>Loading Dock Doors (interior doors)</td>
<td>Closed</td>
</tr>
</tbody>
</table>

8.2.2.9 Measure and record the indoor and outdoor temperatures at the beginning of the test so that their average values can be calculated.

8.2.2.10 Determine the height & temperature factor. The factor is the product of the absolute value of the indoor/outdoor air temperature difference multiplied by the building height. If the factor is less than 200 m°C (1180 °F), perform the test.
• Performing Building Pressure Tests

• Building Set Up
  • Sealing intentional Openings
  • Open air path, interior doors & ceiling tile
  • Time of day (No People)
Testing Procedures

- Performing Building Pressure Tests
- Blower Door Set Up
Testing Procedures

• Performing Building Pressure Tests

  • Testing
    • Baseline Pressure Tests
    • Negative Pressure Tests
    • Positive Pressure Tests

  • Normally 10 readings at setpoint pressures averaged over a 10 second period. Depending upon which standard you are testing to.
Testing Procedures

- Performing Building Pressure Tests

- Testing Accuracy
  - 95% confidence levels (Statistical Calculations)
  - Accuracy affected by deviation between multiple pressure or flow readings
  - Normally caused by wind gusts, opening of doors or poor quality testing techniques
# NEBB Building Pressure Test to ASME Standard E 1827

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Test Date</th>
<th>Test by/</th>
<th>Building/Zone</th>
<th>Test Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Pressure</td>
<td>6/14/2011</td>
<td>Josh Hughes / Shane Dyer</td>
<td>Building &amp; Cottonwood</td>
<td>Minneapolis Blower Door</td>
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<td>6/14/2011</td>
<td>Josh Hughes / Shane Dyer</td>
<td>Building &amp; Cottonwood</td>
<td>Minneapolis Blower Door</td>
</tr>
</tbody>
</table>

## Testing Procedures

### Primary Station 1 Data:

<table>
<thead>
<tr>
<th>Reading</th>
<th>DP/In. H₂O</th>
<th>PA</th>
<th>Flow Setting</th>
<th>Nominal Qᵢₑ</th>
<th>CFM</th>
<th>Envr Qₑₑ</th>
<th>CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3026</td>
<td>75.30</td>
<td>Open</td>
<td>3.741</td>
<td>3.737</td>
<td>75.3</td>
<td>3.741</td>
</tr>
<tr>
<td>2</td>
<td>0.3026</td>
<td>75.30</td>
<td>Open</td>
<td>3.741</td>
<td>3.737</td>
<td>75.3</td>
<td>3.741</td>
</tr>
<tr>
<td>3</td>
<td>0.3026</td>
<td>75.30</td>
<td>Open</td>
<td>3.741</td>
<td>3.737</td>
<td>75.3</td>
<td>3.741</td>
</tr>
<tr>
<td>4</td>
<td>0.3026</td>
<td>75.30</td>
<td>Open</td>
<td>3.741</td>
<td>3.737</td>
<td>75.3</td>
<td>3.741</td>
</tr>
<tr>
<td>5</td>
<td>0.3026</td>
<td>75.30</td>
<td>Open</td>
<td>3.741</td>
<td>3.737</td>
<td>75.3</td>
<td>3.741</td>
</tr>
</tbody>
</table>

### Secondary Station 2 Data:

<table>
<thead>
<tr>
<th>Reading</th>
<th>DP/In. H₂O</th>
<th>PA</th>
<th>Flow Setting</th>
<th>Nominal Qᵢₑ</th>
<th>CFM</th>
<th>Envr Qₑₑ</th>
<th>CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3026</td>
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<td>Open</td>
<td>3.741</td>
<td>3.737</td>
<td>75.3</td>
<td>3.741</td>
</tr>
<tr>
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<td>3.741</td>
</tr>
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<td>3.741</td>
<td>3.737</td>
<td>75.3</td>
<td>3.741</td>
</tr>
</tbody>
</table>

### Notes:

- **Air Handler Not Sealed.** Midstate said there service dept had to do it! Still passed.
Testing Procedures

Leakage Chart

- Allowable Leakage CFM
- Actual Leakage CFM

Pressure

CFM Leakage

0.01  0.1  1

0.089646132, 2.519
0.0918, 1.800
0.299277172, 4.602
0.3014, 3.679
1000  100

NEBB
Testing Procedures

- **Other Envelope Tests**
  - Leak Testing
    - Thermal Imaging of Leaks under Pressure
    - Smoke Tracing
• Other Envelope Tests

• Water Intrusion Testing

• Water flow test under negative pressure

![Testing Procedures](image-url)
NEBB Certification Program

- Experience Requirements
- Required instruments
- Pass Written Examination
- Pass Practical Examination
- Make Application
  - www.NEBB.org
• **Blower Door Equipment**
  
  • **Blower Door Equipment / Software**
    
    • **Minneapolis Blower Door**
      
      www.energyconseratory.com
    
    • **Retrotec**
      
      www.retroec.com
    
    • **Infiltec**
      
      www.infiltecc.com
Testing Procedures

- **Blower Door Equipment**
  - Door panels (hard and soft panels)
  - Fans (8,000 cfm capacity)
  - Drives
  - Gauges
  - Software (ASTM 779)
  - Cases
Testing Procedures

• Thermal Imaging Cameras

• Fluke / Flir / Thermal-Eye / Extech / ..... 

• Key Factors in Selection
  • Resolution
  • Use (temp range)
  • Durability
  • Cost ( $7k to $15k)
Testing Procedures

- Projects?
  - US Army / Navy / Air Force
  - GSA / Federal Buildings
  - Local Code Requirements
  - Owner Requirements
Testing Procedures

- Contract Documents
  - Specification Section?
    - Air Barriers (section 01 or 07)
    - Commissioning
    - TAB / Mechanical
  
Key words

- Air Barrier / Building Envelope
Testing Procedures

• **Who is the normal customer?**
  - Owners
  - General Contractors
  - Commissioners

• **Who has influence for purchase?**
  - Architects
  - Owner
  - Commissioner
QUESTIONS ?