Envelope Commissioning Scope

- Inspection Based instead of check sheet based
- Normal Cx Specification 01 9119
- Components
  - Walls
  - Footings & Floors
  - Roofs
  - Windows & Doors
- Verification
  - Water Barrier
  - Air Barrier
  - Vapor Barrier
  - Thermal Barrier
Envelope Commissioning Process

- Follows similar process as other disciplines
  - Design Review (Details)
  - Specification Review (Materials & Tests)
  - Submittal Review (Compliance)
- Installation Inspections
  - Prior to Air Barrier installation
  - During Air Barrier and Thermal Barrier installation
  - At Air Barrier completion
  - At roof completion
  - At door and window trim installation
Follows similar process as other disciplines (Continued)

- Testing Observation & Documentation
- Issue log resolution
- Commissioning Meeting Management
- Commissioning Report
- Warranty Inspection
• Installation Inspections
  – Field Observations: Envelope

- Low spot with no drain
- Flashing obstructs drainage
- Incorrect installation
• **Thermal Performance Tests**

Infrared Thermography
Envelope Testing Scope

- **Field Tests**
  - Whole building pressure tests
  - Assembly water intrusion tests
  - Roof water intrusion tests
  - Thermal intrusion tests
  - Adhesion pull tests

- **Factory Tests** (Materials Certification Tests)
  - Assembly wind test
  - Window thermal transmittance tests
  - Assembly thermal conductance tests
  - Materials leakage and transmittance tests
• Envelope Construction

• Walls
  • Rainwater Control
  • Air Control Layer
  • Vapor Control Layer
  • Thermal Control Layer

Building Air Leakage

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

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

- Envelope Construction
- Doors and Windows
  - Thermal Transfer
  - Water Channel & Leakage
  - Air Leakage
  - Expansion and Contraction
• **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 $15,000 to $45,000 annual added utility costs

  • **Tested building**

    Tight building could be as low as 0.05 – 0.075 CFM / Square Foot of air leakage
Building Air Leakage

- **Design Leakage Rates**
- **Commercial Guide Standards**
- **ACE Standard (ASTM E779)**
  - 0.25 CFM @75PA / SF Barrier
- **NEBB Standard (ASTM E779 ASTM E1827)**
  - 0.40 – 0.16 CFM @50PA / SF Barrier
- **Air Barrier SF Calculation**
### Design Leakage Rates

**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>0.48 L/s / m² (0.10 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Canada</td>
<td>0.48 L/s / m² (0.10 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Industry</td>
<td>0.48 L/s / m² (0.10 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.92 L/s / m² (0.40 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Corps of Engineers</td>
<td></td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Corps of Engineers 2012 Proposed</td>
<td></td>
<td>0.72 L/s / m² (0.15 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Dept. of the Navy</td>
<td></td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Dept. of the Air Force</td>
<td></td>
<td>1.92 L/s / m² (0.40 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</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&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Warehouses</td>
<td>0.62 L/s / m² (0.13 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Repair Shops</td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.92 L/s / m² (0.40 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Hospitals</td>
<td>0.48 L/s / m² (0.10 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>1.20 L/s / m² (0.25 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Housing Units</td>
<td>0.77 L/s / m² (0.16 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td></td>
</tr>
<tr>
<td>ASHRAE&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.48 L/s / m² (0.10 cfm&lt;sub&gt;50&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>0.60 cfm&lt;sub&gt;75&lt;/sub&gt; / ft&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> Includes ventilation systems.

<sup>2</sup> Lowest leakage rate is 0.48 L/s / m² (0.10 cfm<sub>50</sub> / ft<sup>2</sup>) for all national standards and 0.48 L/s / m² (0.10 cfm<sub>50</sub> / ft<sup>2</sup>) for all building standards.

<sup>3</sup> ASHRAE Standard 62.2-2010.
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 0.10 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”]
Building Air Leakage

- **Design Leakage Rates**

- **Standard Calculation of Air Barrier SF**
  - Area of the Top Story Roof
  - Area of the Bottom Story Floor
  - Area of the walls air barrier

- **Calculating standard Ventilation leakage rates**
  - From pressure test calculation Air Barrier SF x the leakage rate = Leakage CFM @ 75PA

- **Use the following formula to convert to 0.02”**

\[
CFM = \sqrt{\frac{Operating\ Building\ Pressure \times (Leakage\ CFM\ at\ 75\ PA)^2}{Test\ Pressure}}
\]
Limitations of air Leakage Tests

Whole Building Tests

- Size < 150,000 SF Blower Door (Rate = <0.25)
- Size > 150,000 SF HVAC System Special Design
- Temperature x Height < 1820 Degree Feet (40 degrees x 45’ = 1800)
- Wind < 6 MPH or gusting 4 MPH over steady state wind speed
- Unoccupied only
Limitations of air Leakage Tests

• Whole Building Tests
  • Blower doors 1-20 fans maximum
  • Installed on leeward side of building
  • Controlled as one unit
  • Must do Positive Pressure and Negative Pressure tests to meet ASTM standards
• Limitations of air Leakage Tests

• Component Section Tests
  • Test zones
  • Test wall / window sections
  • No total leakage rate
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
Testing Standards

- USACE
- NEBB
- ASTM E779 (Residential)
- ASTM E1827 (Residential)
- CIBSE TM23
Testing Procedures

Building Set Up

TABLE 8-1: Recommended Test Envelope Conditions

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Envelope Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust fans with back draft dampers</td>
<td>Sealed</td>
</tr>
<tr>
<td>Supply fans with back draft dampers</td>
<td>Sealed</td>
</tr>
<tr>
<td>Furnace room door for furnace outside test zone</td>
<td>Closed</td>
</tr>
<tr>
<td>Combustion air intake damper for boilers</td>
<td>Closed</td>
</tr>
<tr>
<td>Outside air intake damper for Air Handling Unit inside test zone</td>
<td>Sealed</td>
</tr>
<tr>
<td>Outside air intake for Air Handling Unit inside test zone without dampers</td>
<td>Sealed</td>
</tr>
<tr>
<td>Exhaust, Air Handling Units, Make-up Air Units, Energy Recovery Units, Supply fans</td>
<td>Off</td>
</tr>
<tr>
<td>Furnace, Fan Coil Units, Boilers, Gas Hot Water Heaters, All equipment requiring</td>
<td></td>
</tr>
<tr>
<td>combustion air (including kitchen equipment, HVAC, etc.)</td>
<td></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>Vented combustion appliance</td>
<td>Off</td>
</tr>
<tr>
<td>Ventilation to other zones</td>
<td>Off</td>
</tr>
<tr>
<td>Varnished</td>
<td>Closed and Latched</td>
</tr>
<tr>
<td>Exterior doors</td>
<td>Sealed</td>
</tr>
<tr>
<td>Varnished, air conditioners</td>
<td>Closed and Latched</td>
</tr>
<tr>
<td>Through the wall air conditioning 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</td>
<td>Sealed</td>
</tr>
<tr>
<td>into the test zone</td>
<td></td>
</tr>
<tr>
<td>All electrical conduits going from inside the test zone to</td>
<td>Sealed</td>
</tr>
<tr>
<td>outside the test zone and back into the test zone</td>
<td></td>
</tr>
<tr>
<td>Openings within the test zone</td>
<td>Open</td>
</tr>
<tr>
<td>Floor drains and plumbing traps</td>
<td>Fixed</td>
</tr>
<tr>
<td>Elevator access point openings</td>
<td>Closed</td>
</tr>
<tr>
<td>Elevator Doors</td>
<td>Closed</td>
</tr>
<tr>
<td>Elevator Door Frame opening between the elevator door and frame if the elevator</td>
<td>Sealed</td>
</tr>
<tr>
<td>connects an area outside the air barrier</td>
<td></td>
</tr>
<tr>
<td>Elevator Door Frame spacing between the elevator door and frame if the elevator</td>
<td>Open</td>
</tr>
<tr>
<td>connects an area within the air barrier</td>
<td></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>

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

6.2.2.10 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 (1100 °F), perform the test.
Testing Procedures

- 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

  - 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.
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

**Primary Station 1 Data:**

<table>
<thead>
<tr>
<th>Reading</th>
<th>DP/in. H₂O</th>
<th>PA</th>
<th>Flow Setting</th>
<th>Nom Q&lt;sub&gt;env&lt;/sub&gt;</th>
<th>Env Q&lt;sub&gt;env&lt;/sub&gt;</th>
<th>Fan 1</th>
<th>Fan 2</th>
<th>Fan 3</th>
<th>Fan 4</th>
<th>Fan 5</th>
<th>Fan 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3026</td>
<td>75.30</td>
<td>Open</td>
<td>3.741</td>
<td>3.717</td>
<td>75.3</td>
<td>3.741</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.3026</td>
<td>75.30</td>
<td>Open</td>
<td>3.704</td>
<td>3.680</td>
<td>75.3</td>
<td>3.704</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.3022</td>
<td>75.20</td>
<td>Open</td>
<td>3.721</td>
<td>3.697</td>
<td>75.2</td>
<td>3.721</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.2990</td>
<td>74.40</td>
<td>Open</td>
<td>3.669</td>
<td>3.646</td>
<td>74.4</td>
<td>3.669</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.3006</td>
<td>74.80</td>
<td>Open</td>
<td>3.676</td>
<td>3.653</td>
<td>74.8</td>
<td>3.676</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>Reading</th>
<th>Nom Q&lt;sub&gt;env&lt;/sub&gt;</th>
<th>Env Q&lt;sub&gt;env&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.701</td>
<td>3.679</td>
</tr>
</tbody>
</table>

**Baseline Bias**

- **Reading:** 0.2993
- **Value:** 74.47

**Secondary Station 2 Data:**

<table>
<thead>
<tr>
<th>Reading</th>
<th>DP/in. H₂O</th>
<th>PA</th>
<th>Flow Setting</th>
<th>Nom Q&lt;sub&gt;env&lt;/sub&gt;</th>
<th>Env Q&lt;sub&gt;env&lt;/sub&gt;</th>
<th>Fan 1</th>
<th>Fan 2</th>
<th>Fan 3</th>
<th>Fan 4</th>
<th>Fan 5</th>
<th>Fan 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0912</td>
<td>22.70</td>
<td>A</td>
<td>1.817</td>
<td>1.805</td>
<td>22.7</td>
<td>1.817</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.0936</td>
<td>23.30</td>
<td>A</td>
<td>1.821</td>
<td>1.809</td>
<td>23.3</td>
<td>1.821</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0920</td>
<td>22.90</td>
<td>A</td>
<td>1.803</td>
<td>1.792</td>
<td>22.9</td>
<td>1.803</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0924</td>
<td>23.00</td>
<td>A</td>
<td>1.806</td>
<td>1.795</td>
<td>23.0</td>
<td>1.806</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.0896</td>
<td>22.30</td>
<td>A</td>
<td>1.813</td>
<td>1.801</td>
<td>22.3</td>
<td>1.813</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>Reading</th>
<th>Nom Q&lt;sub&gt;env&lt;/sub&gt;</th>
<th>Env Q&lt;sub&gt;env&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.812</td>
<td>1.800</td>
</tr>
</tbody>
</table>

**Secondary Station 2 Baseline Bias**

- **Reading:** 0.0896
- **Value:** 22.31

---

**Notes:**

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

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

• Water Intrusion Testing

• Water flow test under negative pressure
Testing Procedures

- **Other Envelope Tests**

- **Roof Water Intrusion Testing**
  - Water sprinkle roof let evaporate then scan roof.
  - Test at 10:00PM-11:00PM
  - Use infrared at night and capacitance moisture meter during the day
QUESTIONS?

COMMISSIONING CONCEPTS
James Bochat, LEED-AP, NEBB Cx
1010 E. Coral Gables Drive, Phoenix, AZ 85022
(602) 758-0501, (602) 504-8882 Fax
Web: www.cxconcepts.com, Email: jim.bochat@cxconcepts.com