Achieving Tight Buildings through Building Envelope Commissioning.

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Learning Objectives

- Understand current code changes that dictate building envelope air leakage requirements.
- Learn the key steps within the BECx process to achieve a tight building.
- Review mock-up and testing strategies through case studies.
Commissioning the Building Envelope

- Importance of air tightness
- Guidelines and Standards
- Key Steps within BECx Process
- Functional Performance Testing
- Case Studies
1995 NBCC Requirements:

Material Requirements
- 0.02 L/s.m\(^2\) @75Pa

System Requirement
- Class 1 RH < 27%  0.15 L/s/m\(^2\)
- Class 2 RH 27-55  0.10 L/s/m\(^2\)
- Class 3 RH > 55%  0.05 L/s/m\(^2\)

- 1/8” x 1/8” hole in 1 yd\(^2\) represents maximum leakage area to meet system requirement

History

Dr. Neil Hutcheon, 1953

Energy loss through air leakage

- Commercial buildings:
  15% - 35% of total energy use
- Residential buildings:
  30% of total energy use
History

2006:

- D.O.E. - Up to 40% of a building’s energy consumption is due to air leakage.

Credit: Journal of Building Enclosure Design Summer 2011
“Improvement of Air Tightness in U.S. Army Buildings” pgs. 11-13
Oak ridge National Lab - Study

- Test full-scale walls w/ and w/o air leakage in hot box
- Leakage limited to joints at sheathings
- Heat flux increased 25 to 50%

![Graph showing percent increase in heat flux]

Energy Modeling

relationship with the Building envelope

Solar Heat Gain

Air Leakage

U-Factor
Energy Modeling

Energy models:
- Treat all air leakage as infiltration not exfiltration
- Leakage area is only wall, not roof/slab
- Does not account for stack effect
Energy Modeling

- Whole building air test results (ASTM E 779) are expressed as air flow through the wall, roof and floor not just the façade.
- CFM/SF rates must be adjusted accordingly (sometimes doubles flow the flow rate)

Oak Ridge National Lab - Study

Finding relating to energy modeling and air leakage:

- Current Modeling software such as Energy Plus doesn’t do a good job at accounting for energy loses due to air leakage.
  - Calculations are based on conductive losses that show smaller temperatures changes than the rapid temperature changes due to air leakage.
  - There is no interactive term within simulation tools and the magnitude of this term is currently unknown.
- Current models appear to underestimate the energy loss due to air leakage.
- Past studies focuses on lower R-value walls (minimizes energy loss due to leakage compared to higher R-values)
Cost of Leaking Vs Tight Buildings

<table>
<thead>
<tr>
<th>Cost</th>
<th>Past Poor Performance</th>
<th>High Performance</th>
<th>Planned High Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design / Construction</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>BECx / Testing</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Remediation</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improperly sized mech. equip.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Additional heating/cooling</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unanticipated maintenance</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BECx impact on Architect and Contractor</td>
<td>As Architect and Contractor become familiar with BECx, extra costs are minimal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case Study

- Approximate building air leakage rate @ 75PA cfm/ft² was in excess of 3 x the allowable leakage rate of 0.25 cfm/ft²
- A formal test was not performed
- A diagnostic evaluation was conducted in order to identify specific areas of leakage

In the Details:
- The air barrier was not adequately transitioned between systems
- No air barrier was installed at the soffit of the entrances
- Building air leakage rate @ 75 PA = 0.82 cfm/ft²
2011 – CSA Z320-11

- Standard that deals with commissioning of the building as a whole
- New construction and retro commissioning
- Specific systems
  - Architectural systems
  - Vertical/horizontal transportation systems
  - Electrical systems
  - Mechanical systems
  - Control systems and integration
- Annexes for functional performance testing options

History

2006:

NIBS Guideline 3-2006
Exterior Enclosure
Technical Requirements
For the Commissioning Process
### TABLE 2. AIR TIGHTNESS STANDARDS COMPARISON
(FOR A FOUR-STORY BUILDING, 120 x 110Ft., N=0.65)

<table>
<thead>
<tr>
<th>Country</th>
<th>Source</th>
<th>Requirement*</th>
<th>Cfm/sq.ft. at 75 Pa.</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>ASHRAE 189.1-2009</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>TS-1 Commercial Best Practice</td>
<td>5 m3/h/m2 at 50 Pa.</td>
<td>0.36</td>
</tr>
<tr>
<td>U.S.</td>
<td>LEED</td>
<td>1.25 sq. in. EqlA @ 4 Pa. / 100 sq. ft.</td>
<td>0.30</td>
</tr>
<tr>
<td>Germany</td>
<td>DIN 4108-2</td>
<td>1.5 l/h at 50 Pa.</td>
<td>0.28</td>
</tr>
<tr>
<td>UK</td>
<td>TS-1 Commercial Tight</td>
<td>2 m3/h/m2 at 50 Pa.</td>
<td>0.14</td>
</tr>
<tr>
<td>Canada</td>
<td>R-2000</td>
<td>1 sq. in. EqlA @10 Pa. /100 sq. ft.</td>
<td>0.13</td>
</tr>
<tr>
<td>Germany</td>
<td>Passive House Std</td>
<td>0.6 l/h at 50 Pa.</td>
<td>0.11</td>
</tr>
</tbody>
</table>

*USACE requirement is 0.25 cfm/sq. ft. at 75 Pa.

Credit: Journal of Building Enclosure Design Summer 2011 “Improvement of Air Tightness in U.S. Army Buildings” pgs. 11-13

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### History

**2012:**

**ASTM**
- E 2813 – Standard of Practice BECx
- NIBS Guideline 3 – Standard guide subcommittee formed
- Certification and Training subcommittee formed
  - ASTM certification, NIBS training
  - Based on ISO 17024 accreditation
## TWO OPTIONS:

1. ASNI/ASHRAE/IESNA 90.1
2. C402.4

### Construction Document Requirements

- **Materials:** air permeability $\leq 0.004$ cfm/ft$^2$
- **Assemblies:** air permeability $\leq 0.04$ cfm/ft$^2$
- **Whole Building:** air permeability $\leq 0.4$ cfm/ft$^2$
- **Joints/seams** resist negative/positive pressure

### Fenestration Air Leakage Requirements

### Door Air Leakage Requirements

### Vestibule Requirements

### Table: Specifications for Continuous Air Barrier

<table>
<thead>
<tr>
<th>Requirement</th>
<th>IECC</th>
<th>ASHRAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous AB</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Continuous AB in Zones 1-3 (Southern States)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Continuous AB in Semi-heated spaces</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Construction Document Requirements</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Materials: air permeability $\leq 0.004$ cfm/ft$^2$</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Assemblies: air permeability $\leq 0.04$ cfm/ft$^2$</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Whole Building: air permeability $\leq 0.4$ cfm/ft$^2$</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Joints/seams resist negative/positive pressure</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Joints, seams, transitions, and penetrations sealed</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fenestration Air Leakage Requirements</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Door Air Leakage Requirements</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vestibule Requirements</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Fenestration Air Requirements

**TABLE C402.4.3**

<table>
<thead>
<tr>
<th>Fenestration Assembly</th>
<th>Maximum Rate (CFM/Wt)</th>
<th>Test Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>0.20</td>
<td>AAMA/WDMA/CSA101/15.3/A440</td>
</tr>
<tr>
<td>Sliding doors</td>
<td>0.20</td>
<td>or NFRC 400</td>
</tr>
<tr>
<td>Swinging doors</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Skylights — with condensation weepage openings</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>Skylights — all other</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Curtain walls</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Storefront glazing</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Commercial glazed swinging entrance doors</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Revolving doors</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Garage doors</td>
<td>0.40</td>
<td>ANSI/ASMA 105, NFRC 690, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM E 283 at 1.57 pf (75 Pa)</td>
</tr>
<tr>
<td>Rolling doors</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

For SI: 1 cubic foot per minute = 0.47/La, 1 square foot = 0.093 m².

a. The maximum rate for windows, sliding and swinging doors, and skylights is permitted to be 0.3 cfm per square foot of fenestration or door area when tested in accordance with AAMA/WDMA/CSA101/15.3/A440 at 0.25 psi (175 Pa).

What is an Air Barrier?
## What is an Air Barrier?

- **Materials with air permeability ≤0.004 cfm/ft²**
- **Compliant Materials**
  - Plywood ≥ 3/8 in. thick
  - Oriented Strand Board ≥ 3/8 in. thick
  - Extruded Insulation Board ≥ 1/2 in. thick
  - Foil-back Insulation Board ≥ 1/2 in. thick
  - Closed-cell spray foam (min. density 1.5 pcf and thickness ≥ 1-1/2 in.)
  - Open-cell spray foam with density 0.4-1.5 pcf and thickness ≥ 4-1/2 in.
  - Exterior or interior gypsum board ≥ 1/2 in.
  - Cement board ≥ 1/2 in.
  - Built-up roofing membrane
  - Mod-bit roofing membrane
  - Fully-adhered single-ply roofing membrane
  - Portland cement/sand parge or gypsum plaster ≥ 3/8 in. thick
  - Cast-in-place or precast concrete
  - Fully grouted concrete block masonry
  - Sheet steel or aluminum

## Nature Wants Equilibrium

- High To Low
- Hot To Cold
- Wet To Dry
Air Flow

Air flow rate depends on:

- Pressure difference
- Size of hole
- Location of hole

Orifice Leak
ENVIRONMENTAL SEPARATION

- Air barriers
- Vapor barriers
- Drainage layers
- Thermal barriers
Commissioning Phases

- Pre-Design Phase
- Design Phase
- Pre-Construction Phase
- Construction Phase
- Operations & Maintenance Phase

Building Enclosure Commissioning Selection Guide
Design Phase

- Review design against OPR and BOD
- Perform hygrothermal computer modeling (WUFI & Therm)
- Review construction sequencing and scheduling
- Write BECx and functional performance testing specifications
HVAC or building Envelope?

- Air intake, but interior room forms the duct.
- Floor is waterproofed with roofing membrane.
- Room hemorrhages air.
Testing Considerations

- Difficulty in achieving the OPR
- Complexity of the design – How wild is the Architect’s dream and what’s the climate
- Number of systems - cladding Matrix
- Are all interior spaces conditioned the same?
- Expectations of trades.
Pre-construction Phase

- Start-up meeting with all parties involved
- Review of shop drawings
- Review of proposed materials for compatibility
- Review of ownership/sequence
- Finalize testing protocols
- Document mock-up construction and testing.
Pre-construction Phase

Mockup:

- To be built by the trades
- Represent project design and materials
- May be stand-alone or part of the final construction
- To include as many typical details as possible
- To be tested for compliance
- Sets the standard of care
Construction Phase

- Review Quality control by contractors Q/C
- Observe/perform functional performance testing
- Construction observations/inspections
- As-needed BECx meetings
- Update BECx plan
O & M Phase

- Whole building testing
- Infrared scanning
- Warranty package
- Final BECx record
QUESTIONS?
COMMENTS?
INSULTS?

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