WHAT’S NEXT?
EVOLUTION OF THE BUILDING ENCLOSURE
AND FUTURE TRENDS

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Learning Objectives:

• Understand the evolution of building enclosures, and current accelerating trends.

• Recognize this evolution on previously segmented industries, and their ongoing unification.

• Understand challenges associated with properly integrating enclosure components and systems.

• Acknowledge holistic approaches to achieving code compliance and meeting owner expectations.
Topics

1. Building Code Requirements and Industry Standards
2. Speed to Market | Integrated Project Delivery | Delegated Design
3. Factory Fabrication of Building Materials and Systems
4. Field Quality Control Testing
5. Building Enclosure Commissioning (BECx)
Building Code Requirements
and Industry Standards

Topic 1
Evolution

- Building Code Requirements and Industry Voluntary Standards
  - ASHRAE
  - ICC Codes (IBC and IECC)
  - CABO MEC
  - BOCA
  - UBC
  - ASTM
<table>
<thead>
<tr>
<th>Era</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970s</td>
<td><strong>1976 UBC</strong>: Vapor barriers required in built-up roof construction in cold climates</td>
</tr>
<tr>
<td></td>
<td><strong>1979 UBC</strong>: No change from 1976 requirements</td>
</tr>
</tbody>
</table>
### Evolution: Vapor Retarders

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980s</td>
<td><strong>1981 BOCA:</strong> No reference to vapor retarders/barriers</td>
</tr>
<tr>
<td></td>
<td><strong>1982 UBC:</strong> 1976 requirements and reference to vapor barriers in insulation requirements</td>
</tr>
<tr>
<td></td>
<td><strong>1985 UBC:</strong> No change from 1982 requirements</td>
</tr>
<tr>
<td></td>
<td><strong>1987 BOCA:</strong> “Vapor-type barrier” indicated for the interior of exterior walls where cavity is not adequately ventilated</td>
</tr>
<tr>
<td></td>
<td><strong>1988 UBC:</strong> Vapor retarder first introduced as a defined term. Vapor barrier requirements/references largely unchanged from 1985</td>
</tr>
<tr>
<td></td>
<td><strong>1989 ASHRAE 90.1:</strong> Vapor retarders recommended for consideration to prevent moisture from collecting within the envelope</td>
</tr>
<tr>
<td>Year</td>
<td>Code</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>1990</td>
<td>BOCA</td>
</tr>
<tr>
<td>1991</td>
<td>UBC</td>
</tr>
<tr>
<td>1992</td>
<td>CABO MEC</td>
</tr>
<tr>
<td>1993</td>
<td>BOCA</td>
</tr>
<tr>
<td>1994</td>
<td>UBC</td>
</tr>
<tr>
<td>1996</td>
<td>BOCA</td>
</tr>
<tr>
<td>1997</td>
<td>UBC</td>
</tr>
<tr>
<td>1998</td>
<td>IECC</td>
</tr>
</tbody>
</table>
Evolution: Vapor Retarders

2000s

2000 IBC: Approved interior noncombustible vapor retarder required for exterior walls
2000 IECC: Largely unchanged from 1998 requirements

2003 IBC: Approved vapor retarder required for exterior walls
2003 IECC: No change from 2000 requirements

2006 IBC: No vapor retarder requirements
2006 IECC: Vapor retarder required on warm-in-winter side of the insulation for walls/floors/ceilings, except for Climate Zones 1-3.

2009 IBC: Interior Class I or II vapor retarder required for framed walls in Climate Zones 5, 6, 7, 8, and Marine 4. Class III vapor retarders permitted for some conditions.
2009 IECC: No vapor retarder requirements
<table>
<thead>
<tr>
<th><strong>Evolution: Vapor Retarders</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2010s</strong></td>
</tr>
<tr>
<td><strong>2012 IBC:</strong> Interior Class I or II vapor retarder required for framed walls in Climate Zones 5, 6, 7, 8, and Marine 4.</td>
</tr>
<tr>
<td><strong>2012 IECC:</strong> No vapor retarder requirements</td>
</tr>
</tbody>
</table>

| **2015 IBC:** 2012 requirements, plus: Class I or II vapor retarders not allowed at interior of framed walls in Climate Zones 1 and 2, and Class I vapor retarders not allowed at interior of framed walls in Climate Zones 3 and 4. |
| **2015 IECC:** No vapor retarder requirements |

| **2018 IBC:** 2015 requirements, plus: Class I vapor retarders allowed for exterior walls in Climate Zone Marine 4. |
| **2018 IECC:** No vapor retarder requirements |
Evolution: Air Barrier

2000s

**2001 ASHRAE 90.1:** Areas of the building envelope indicated to be sealed, caulked, gasketed, or weather-stripped to minimize air leakage.

**2004 ASHRAE 90.1:** No change from 2001 requirements

**2007 ASHRAE 90.1:** No change from 2001 requirements

**2009 IECC:** Air Barrier term introduced, but no air barrier requirements

AIR BARRIER. Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.
Evolution: Air Barrier

**2010s**

**2010 ASHRAE 90.1:**
- Continuous air barrier first introduced as defined term
- Continuous air barrier required, except in semi-heated spaces in Climate Zones 1-6, and in single-wythe CMU buildings in Climate Zone 2B.
- First inclusion of identified acceptable materials/assemblies for continuous air barriers

**2012 IECC:** Continuous air barrier required, except in Climate Zones 1, 2, and 3
Evolution: Air Barrier

2010s

2013 ASHRAE 90.1: No change from 2010 requirements

2015 IECC:
- Continuous air barrier required, except in Climate Zone 2B
- Testing per ASTM E779 (fan pressurization test for whole building air leakage) introduced as a performance compliance option over prescriptive requirements for air barriers
Evolution: Air Barrier

2010s

2016 ASHRAE 90.1:
- Continuous air barrier required, except in semi-heated spaces in Climate Zones 0-6, and in single-wythe CMU buildings in Climate Zone 2B.
- Clarification added that continuous air barrier is to extend over all surfaces of the building envelope (at the lowest floor, walls, and roof)
- Option added for continuous air barrier compliance via whole building pressurization testing

2018 IECC: No change from 2015 requirements
Evolution: Whole Building Air Leakage Testing

1990s


Evolution: Whole Building Air Leakage Testing

2010s

**2015 IECC:** Option added for testing per ASTM E779 (*whole building pressurization testing*) in lieu of prescriptive requirements for the thermal envelope, including continuous air barrier requirements.

**2016 ASHRAE 90.1:** Option added for continuous air barrier material/assembly compliance via whole building pressurization testing.

**2018 IECC:** No change from 2015 requirements.

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C402.5 Air leakage—thermal envelope (Mandatory). The building shall comply with whole-building pressurization testing in accordance with Section 5.4.3.1.3(a) or with the continuous air barrier requirements in Section 5.4.3.1.3(b) or 5.4.3.1.3(c).

a. Whole-building pressurization testing shall be conducted in accordance with ASTM E779 or ASTM E1827 by an independent third party. The measured air leakage rate of the building envelope shall not exceed 0.40 cfm/ft² under a pressure differential of 0.3 in. of water, with this air leakage rate normalized by the sum of the above and below-grade building envelope areas of the conditioned and semiheated space.
Speed to Market
Integrated Project Delivery
Delegated Design

Topic 2
Exterior Interior

THERMAL BREAK

FACE OF BRICK
ALUMINUM DOOR
CONCRETE BALCONY
SEALANT AND BACKER ROD
ALUM. PAN FLASHING
CEMENTITIOUS NON-SHRINK
HYDRAULIC CEMENT COAT
JOINT SEALING TAPE

3”
Delegated Design:
Transferring design responsibility of some portion of the project to a party other than the Designer-of-Record

“Delegated-design solutions require specific input from a professional engineer retained by the constructor, supplier, fabricator, or manufacturer.
--The Construction Specifier, November 2018
(Robinson, Franchuck, Murnane)
Benefits
- Design fees can be reduced
- Project schedule can be improved
- Specialty designs are prepared by specialists with unique knowledge of materials, systems, and construction
- Potential for reduced construction costs

Perils
- Blurred responsibility for interfaces between delegated and prime design elements
- Contractual responsibility can be murky
- Licensing boards and building departments are not consistent regarding prime vs. specialty/delegated design responsibility

Outcome
- More project control ceded to the Contractor
Who is responsible for coordination and interface details with multiple delegated design materials/systems?
Delegated Design: Transferring design responsibility of some portion of the project to a party other than the Designer-of-Record

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design Formed Metal Wall Panels.

B. Structural Performance: Provide metal panel systems capable of withstanding the effects of the following loads, based on testing according to ASTM E 1592:
   1. Wind Speed 90 mph
   2. Importance factor 1.15
   3. Exposure B
   4. Other Design Loads: As indicated on Drawings.
   5. Deflection Limits: For wind loads, no greater than 1/180 of the span.
D. Roofing System Design: Tested by a qualified testing agency to resist the following uplift pressures:

1. Corner Uplift Pressure: As determined by Delegated Design Engineer.
2. Perimeter Uplift Pressure: As determined by Delegated Design Engineer.
3. Field Uplift Pressure: As determined by Delegated Design Engineer.
4. Basic Wind Speed: 90 mph.
5. Wind Exposure: Exposure B.
6. Wind Importance Factor 1.15.
7. Safety Factor: Twice the calculated load.
General Conditions of the Contract for Construction

for the following PROJECT:
(Name and location or address)

THE OWNER:
(Name, legal status and address)

THE ARCHITECT:
(Name, legal status and address)

TABLE OF ARTICLES
1 GENERAL PROVISIONS
2 OWNER
3 CONTRACTOR
4 ARCHITECT
5 SUBCONTRACTORS
6 CONSTRUCTION BY OWNER OR BY SEPARATE CONTRACTORS
7 CHANGES IN THE WORK
8 TIME
9 PAYMENTS AND COMPLETION
10 PROTECTION OF PERSONS AND PROPERTY
11 INSURANCE AND BONDS
12 UNCOVERING AND CORRECTION OF WORK
13 MISCELLANEOUS PROVISIONS
14 TERMINATION OR SUSPENSION OF THE CONTRACT
15 CLAIMS AND DISPUTES

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3.12.4 **Shop Drawings, Product Data, Samples, and similar submittals are not Contract Documents.** Their purpose is to demonstrate how the Contractor proposes to conform to the information given and the design concept expressed in the Contract Documents for those portions of the Work for which Contract Documents require submittals. Review by the Architect is subject to the limitations of Section 4.2.7. Information submittals upon which the Architect is not expected to take responsive action may be so identified in the Contract Documents. Submittals that are not required by the Contract Documents may be returned by the Architect without action.
3.12.10 The Contractor shall **not** be required to provide professional services that constitute the practice of **architecture or engineering** unless such services are **specifically required by the Contract Documents** for a portion of the Work…

3.12.10.1 If professional design services or certifications by design a professional are specifically required of the Contractor by the Contract Documents, the **Owner and the Architect will specify all performance and design criteria** that such services must satisfy…

…the Architect will review and approve or take appropriate action on submittals only for the limited purpose of **checking for conformance with information given and the design concepts expressed** in the Contract Documents.

3.12.10.2 If the Contract Documents require the **Contractor’s design professional** to certify that the work has been performed in accordance with the design criteria, **the Contractor shall furnish such certifications** to the Architect…
<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 35 00</td>
<td><strong>Special Procedures</strong></td>
</tr>
<tr>
<td>01 35 03</td>
<td>Conservation Treatment Procedures</td>
</tr>
<tr>
<td>01 35 13</td>
<td>Special Project Procedures</td>
</tr>
<tr>
<td>01 35 13.13</td>
<td>Special Project Procedures for Airport Facilities</td>
</tr>
<tr>
<td>01 35 13.16</td>
<td>Special Project Procedures for Detention Facilities</td>
</tr>
<tr>
<td>01 35 13.19</td>
<td>Special Project Procedures for Healthcare Facilities</td>
</tr>
<tr>
<td>01 35 13.26</td>
<td>Special Project Procedures for Clean Rooms</td>
</tr>
<tr>
<td>01 35 13.43</td>
<td>Special Project Procedures for Contaminated Sites</td>
</tr>
<tr>
<td>01 35 16</td>
<td>Alteration Project Procedures</td>
</tr>
<tr>
<td>01 35 23</td>
<td>Owner Safety Requirements</td>
</tr>
<tr>
<td>01 35 26</td>
<td>Governmental Safety Requirements</td>
</tr>
<tr>
<td>01 35 29</td>
<td>Health, Safety, and Emergency Response Procedures</td>
</tr>
<tr>
<td>01 35 29.13</td>
<td>Health, Safety, and Emergency Response Procedures for Contaminated Sites</td>
</tr>
<tr>
<td>01 35 33</td>
<td>Infection Control Procedures</td>
</tr>
<tr>
<td>01 35 43</td>
<td>Environmental Procedures</td>
</tr>
<tr>
<td>01 35 43.13</td>
<td>Environmental Procedures for Hazardous Materials</td>
</tr>
<tr>
<td>01 35 43.16</td>
<td>Environmental Procedures for Toxic Materials</td>
</tr>
<tr>
<td>01 35 46</td>
<td>Indoor Air Quality Procedures</td>
</tr>
<tr>
<td>01 35 53</td>
<td>Security Procedures</td>
</tr>
<tr>
<td>01 35 63</td>
<td>Sustainability Certification Project Requirements</td>
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<tr>
<td>01 35 66</td>
<td>Sustainability Certification Project Procedures</td>
</tr>
<tr>
<td>01 35 73</td>
<td>Delegated Design Procedures</td>
</tr>
<tr>
<td>01 35 91</td>
<td>Period Treatment Procedures</td>
</tr>
</tbody>
</table>
1.1.A. Section Includes: Administrative and procedural requirements for portions of the Work the design of which is delegated to the Contractor.

1.1.B.1 Delegated: Means transferred by the Architect to the Contractor.
1.3.B. **The Contractor is professionally liable** for delegated design work, **including design, engineering**, and conformance to specified performance requirements.
3.1.A. Unless otherwise indicated or specified, maintain the design intent and conform to the performance requirements indicated on the Drawings and in the Specifications, as determined by the Architect.

B. Engage a qualified professional structural engineer to design connection details and determine fastener types and sizes.

1. Fasteners or connections may neither conflict with nor require revision to the finish profiles indicated or the supporting work.
2. Connections may not impose eccentric loading, nor induce twisting or warping to the supporting structure.
3. Connections must be designed to accommodate potential and actual misalignment of adjacent work within tolerances specified in other Sections.
Section 107 - Submittal Documents

107.3.4.1 Deferred submittals

- Deferral of any submittal items shall have **prior approval of the building official**. The registered design professional in responsible charge shall **list the deferred submittals** on the construction documents for review by the building official.

- Documents for deferred submittal items shall be submitted to the **registered design professional in responsible charge who shall review them and forward them to the building official** with a notation indicating that the deferred submittal documents have been reviewed and found to be in general conformance to the design of the building.

- The deferred submittal items **shall not be installed** until the deferred submittal documents have been approved by the building official.
Project Workflow for a Project with Integrated Project Delivery – Unitized Curtain Wall (Design Assist)

- Architect/Construction Manager selected
- Schematic Design
- Design Development
- Curtain wall subcontract bid/interviews
- Review proposed curtain wall systems/manufacturers
- Curtain wall subcontract awarded
- Design-assist meetings commence
- 100% Construction Documents (Issued for permit/construction)
- Design-assist meetings continue
- Bulletins issued by Architect
- Curtain wall shop drawings issued for preliminary review
- Fabrication commences (dye profiles, etc.)
- Review and comment on curtain wall shop drawings
- Revise curtain wall shop drawings
- Additional fabrication
- Performance mock-up
- Shop drawing calculations issued
- Installation commences
- Shop drawings approved by CM and DOR
- Installation continues and shop drawings revised throughout project
2016: ~75% of roofs are single ply membranes
U. S. Low-Slope Commercial Roofing Market
2000 - 2015
(Percent Share)

July 1, 2017
TEGNOS Research, Inc.
Roofs were previously manufactured at the site. Now they are assembled at the site. –Rolf Snobeck
PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide cold-applied, 3-ply roofing system by ☑️ Equivalent products and systems manufactured by companies indicated below may also be accepted by the Architect, subject to compliance of the substituted product with the Contract requirements, providing all roof system material components meeting physical properties indicated below:

1. ☑️
2. ☑️

2.2 ROOFING MEMBRANE PLIES

1. Tensile Strength: 133 pound-force per inch MD, 258 pound-force per inch XMD, ASTM D146.
2. Tear Resistance per ASTM D 689:
   c. Puncture Resistance per ASTM D 781: 42 inch-pounds.
3. Materials per 100 sq ft (9.3 m2) of Roof Area
   a. Asphalt Primer (If required): 0.5 gallons.
4. Interply: Manufacturer’s BUR Adhesive or MBR Cold Application Adhesive:
   a. Incline per foot Adhesive Type Per 100 sq ft (9.3 m2) l/m2
   b. Up to 3” (250 mm/m) JM BUR Adhesive 61/2-71/2 gal 2.7-3.1
   c. or MBR Cold Application Adhesive
5. Surfacing: Per 100 square feet:
   a. Gravel: 400 pounds.
   b. Slag: 300 pounds.
   c. Granules: 60 to 100 pounds.
6. Adhesive Type: Manufacturer’s BUR Adhesive or MBR Cold Application Adhesive at 3 to 4 gallons.
You can have something:

- **FAST & CHEAP** but it won’t be good quality
- **CHEAP & GOOD QUALITY** but it won’t be quick or on time
- **ON TIME & GOOD QUALITY** but it won’t be cheap
MBI founded in 1983
Improving Construction Efficiency & Productivity with Modular Construction

Recently, the National Institute of Standards and Technology (NIST) requested that the National Research Council (NRC) appoint an ad hoc committee of experts to provide advice for advancing the competitiveness and productivity of the U.S. construction industry. The committee’s specific task was to conduct a workshop to identify and prioritize technologies, processes, and deployment activities that have the greatest potential to advance significantly the productivity and competitiveness of the capital facilities sector of the U.S. construction industry in the next 20 years. The committee identified five breakthroughs to improve the efficiency and productivity of the construction industry, including breakthrough number three: “Greater use of prefabrication, preassembly, modularization, and off-site fabrication techniques and processes.”
Report of the Results of the
2014 Off-Site Construction Industry Survey
QUESTION 6

For this project, what were the actual benefits realized by using off-site construction?

- Schedule Advantage/Speed to Market: 73.2%
- Quality: 62.5%
- Cost-Effectiveness: 50.8%
- Site Operations: 41.1%
- Client Satisfaction: 38.8%
- Safety: 38.5%
- Cost: 31.8%
- Weather Concerns: 28.1%
QUESTION 9
In the next 12 months, how often do you anticipate using off-site construction?

Not at All: 7.4%
Less: 9.4%
The Same: 50.0%
More: 33.2%
Field Quality Control Testing

Topic 4
Is the Quality of Building Enclosure finally being taken seriously?

- It depends...
- What is quality?
  - Quality refers to the project requirements established by the contract documents.
  - Quality does not have a universal definition.
  - Quality is always **project-specific**.
- Owner’s expectations:
  - Developer of condominiums vs. healthcare, e.g.
  - Initial cost (testing) versus long-term risk trade-offs
  - Impact on schedule
- Contractor risk management:
  - Litigation and insurance company concerns
  - Water intrusion claims make up more than 70 percent of construction litigation
3.1. FIELD QUALITY CONTROL

A. Testing Agency: [Owner will engage] [Engage] a qualified testing agency to perform tests and inspections.

B. Perform the following tests:

1. **Flood Testing**: Flood test each roofing area for leaks, according to recommendations in ASTM D 5957, after completing roofing and flashing.
   a. Flood to an average depth of \[2-1/2\] inches for \[48\] hours.

2. **Infrared Thermography**: Testing agency shall survey entire roof area using infrared color thermography according to ASTM C 1153.
   a. After infrared scan, locate specific areas of leaks by electrical capacitance/impedance testing or nuclear hydrogen detection tests.
   b. After testing, repair leaks, repeat tests, and make further repairs until roofing and flashing installations are watertight.

3. **Electrical Capacitance/Impedance Testing**: Testing agency shall survey entire roof area for entrapped water within roof assembly according to ASTM D 7954/D 7954M.

4. **Nuclear Hydrogen Detection Testing**: Testing agency shall survey entire roof area for entrapped water within roof assembly according to SPRI/RCI NT-1.

5. **Low-Voltage Electrical Conductance Testing**: Testing agency shall survey entire roof area and flashings to locate discontinuity in the roof membrane using [an exposed metal electrical loop to create an electrical field tested with handheld probes].

C. Prepare test and inspection reports.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>WHO</th>
<th>WHAT</th>
<th>WHERE</th>
<th>HOW</th>
<th>WHEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPONENT / SYSTEM TO BE TESTED</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QUANTITY / TIMING OF TESTS</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>LOCATIONS OF TESTS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEST STANDARD / DESCRIPTION OF TEST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>TEST METHOD / METHODOLOGY</td>
<td></td>
<td></td>
<td></td>
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<td>X</td>
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<tr>
<td>PASS/FAIL CRITERIA</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PARTY RESPONSIBLE FOR TESTING / REPORTING</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REPORTING REQUIREMENTS</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>REQUIRED ADDITIONAL TESTING IN CASE OF FAILED TESTS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PARTY RESPONSIBLE FOR COSTS ASSOCIATED WITH FAILED TESTS</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Effect of Load Rate on Pull-Off Adhesion Strength

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>ASTM D4541</th>
<th>ASTM D7234</th>
<th>ABAA 0002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Load Rate</td>
<td>150 psi/sec</td>
<td>30 psi/sec</td>
<td>0.97 psi/sec (58 psi/min)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>or 6 crank revolutions/min</td>
</tr>
</tbody>
</table>
The Effect of Load Rate on Pull-Off Adhesion Strength

~1 psi / second → 22 psi
~40 psi / second → 41 psi

~86% increase

<table>
<thead>
<tr>
<th>PRACTICE</th>
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<th>ASTM D7234</th>
<th>ABAA 0002</th>
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</tr>
<tr>
<td>PRACTICE</td>
<td>PARAGRAPHS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Depressurization (or Pressurization) with Infrared Scanning Techniques</td>
<td>4.2.1 and 7.2 to 7.2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoke Tracer or Theatrical Fog in Conjunction with Building Pressurization or Depressurization</td>
<td>4.2.2 and 7.3 to 7.3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Depressurization (or Pressurization) in Conjunction with Airflow Measurement Devices, or Anemometers</td>
<td>4.2.3 and 7.4 to 7.4.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generated Sound in Conjunction with Sound Detection</td>
<td>4.2.4 and 7.5 to 7.5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracer Gas</td>
<td>4.2.5 and 7.6 to 7.6.4</td>
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<td></td>
</tr>
<tr>
<td>Chamber Pressurization or Depressurization in Conjunction with Smoke Tracer or Theatrical Fog</td>
<td>4.2.6 and 7.7 to 7.7.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamber Depressurization in Conjunction with Leak Detection Liquid</td>
<td>4.2.7 and 7.8 to 7.8.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Building enclosure is tested to quantify the air tightness. The test measures air leakage rates through the enclosure under controlled pressurization and depressurization. Requirements for whole building testing are:

- State of Washington
- United States General Services Administration
- United States Army Corps of Engineers projects
- Performance-based option (IECC) that many designers are requiring.

IECC 2021? 2024?
C402.5.1.2 Building test. The completed building shall be tested and the air leakage rate of the building envelope shall not exceed 0.40 cfm/ft² at a pressure differential of 0.3 inches water gauge (2.0 L/s x m² at 75 Pa) at the upper 95 percent confidence interval in accordance with ASTM E 779 or an equivalent method approved by the code official. A report that includes the tested surface area, floor area, air by volume, stories above grade, and leakage rates shall be submitted to the building owner and the Code Official. If the tested rate exceeds that defined here, a visual inspection of the air barrier shall be conducted and any leaks noted shall be sealed to the extent practicable. An additional report identifying the corrective actions taken to seal air leaks shall be submitted to the building owner and the Code Official and any further requirement to meet the leakage air rate will be waived.

C402.5.1.1 Air barrier construction. The continuous air barrier shall be constructed to comply with the following:

5. Construction documents shall contain a diagram showing the building’s pressure boundary in plan(s) and section(s) and a calculation of the area of the pressure boundary to be considered in the test.
Proposed Scope of Guide

- Assist in the specification, design, and **performance testing** of field-constructed exterior wall assemblies
- Testing procedures for water penetration resistance, air leakage resistances, etc.
- Exterior wall mock-ups:
  - Curtain walls, windows, doors, masonry walls, precast concrete, cast-in-place concrete, EIFS, **roofing interfaces**, stucco, wood siding, metal panels, sealants, appurtenances, **penetrations**, louvers, etc.
- Intersections between wall systems
Building Enclosure Commissioning (BECx)

Topic 5
Building Enclosure Commissioning \((BEC_x)\)

History of Process Development

- **2006**
  - NIBS Guideline 3 - \(BEC_x\) Process (Edition 1)

- **2012**
  - NIBS Guideline 3 - \(BEC_x\) Process (Edition 2)
  - ASTM E2813 - *Standard Practice for BEC_x* (Edition 1 – numerous subsequent revisions)

- **2014**
Building Enclosure Commissioning (BEC\textsubscript{x})

NIBS GL3

- “The purpose of this guideline is to describe the specific application of the BECx process described generically in ASHRAE Guideline 0.”
- “...intended to be usable by all owners for all building types.”
- Not a ‘one-size-fits-all’ approach. BECx objectives may vary by:
  - Type of Owner
  - Occupancy
  - Use
  - Size
  - Project Requirements
- Describes a process
4.1 This practice establishes two levels of BEC\textsubscript{x}: Fundamental and Enhanced.

1.4 This practice includes mandatory BEC\textsubscript{x} Performance Testing Requirements (Annex A2) approved for use with this practice, to evaluate the performance and durability of enclosures, materials, components, systems, and assemblies.

1.5 This practice mandates independent, third-party design peer review during the Design Phase of both Fundamental and Enhanced BEC\textsubscript{x}.

1.6 This practice recognizes that the OPR are exterior walls, roofs, and curtain walls.
## Primary Differences

<table>
<thead>
<tr>
<th>Fundamental BECx</th>
<th>Enhanced BECx</th>
</tr>
</thead>
<tbody>
<tr>
<td>BECx provider engaged during Design phase</td>
<td>BECx provider engaged during pre-design phase</td>
</tr>
<tr>
<td>Review of preliminary OPR</td>
<td>Assist with preliminary OPR development</td>
</tr>
<tr>
<td>Minimum of 1 design peer review at CD completion</td>
<td>Minimum of 3 design peer reviews at SD, DD, and CD phases</td>
</tr>
<tr>
<td>9 total mandatory field mock-up test types</td>
<td>11 total mandatory field mock-up test types</td>
</tr>
<tr>
<td>11 total mandatory field in-situ test types</td>
<td>15 total mandatory field in-situ test types</td>
</tr>
</tbody>
</table>
# Building Enclosure Commissioning (BECx) ASTM E2947

## Table A2.1 – BECx Performance Testing Requirements

<table>
<thead>
<tr>
<th>Property</th>
<th>Standard Designation</th>
<th>Title</th>
<th>Lab System Testing</th>
<th>Enhanced Field Mockup Testing</th>
<th>In-Situ Field Testing</th>
<th>Fundamental Field Mockup Testing</th>
<th>In-Situ Field Testing</th>
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<tbody>
<tr>
<td>Water penetration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>ASTM E331</td>
<td>Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference</td>
<td>L (M)</td>
<td>(OF)</td>
<td>(OF)</td>
<td>(OF)</td>
<td>(OF)</td>
</tr>
<tr>
<td></td>
<td>ASTM E514</td>
<td>Test Method for Water Penetration and Leakage Through Masonry</td>
<td>. .</td>
<td>(OF)</td>
<td>(OF)</td>
<td>(OF)</td>
<td>(OF)</td>
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<tr>
<td></td>
<td>ASTM C1601</td>
<td>Test Method for Field Determination of Water Penetration of Masonry Wall Surfaces</td>
<td>. .</td>
<td>(OF)</td>
<td>(OF)</td>
<td>(OF)</td>
<td>(OF)</td>
</tr>
<tr>
<td>Static water penetration</td>
<td>ASTM E1105</td>
<td>Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference</td>
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<td>(2X)</td>
<td>(1X)</td>
<td>(1X)</td>
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<tr>
<td></td>
<td>AAMA 501.2</td>
<td>Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems</td>
<td>. .</td>
<td>(1X)</td>
<td>(1X)</td>
<td>(1X)</td>
<td>(1X)</td>
</tr>
</tbody>
</table>
Building Enclosure Commissioning (BECx)

ASTM E2947

1.1 Purpose—This guide provides procedures, methods and documentation techniques that may be used in the application of the building enclosure commissioning (BECx) process. This guide is complementary to Practice E2813 and is aligned with ANSI/ASHRAE/IES Standard 202 and ASHRAE Guideline 0.

1.2 Extent—The process outlined in this standard guide applies to each building delivery phase from pre-design through Owner occupancy and operation. The specific application of this guide may vary to suit the Owner, the project delivery method and the building project as outlined in the Owner’s Project Requirements (OPR).

3.1.1 ASTM E2947 Terminology of Building Enclosures.
3.1.2 ASHRAE Guideline 0, Section 4, Definitions.
3.1.3 ANSI/ASHRAE/IES Standard 202, Section 3, Definitions.
3.2 Definitions of Terms Specific to This Standard:
3.2.1 The following definitions, abbreviations, and acronyms are specific to the implementation of the commissioning process.

3.2.2 Building enclosure, the term “building enclosure” and “enclosure” refer collectively to materials, components, systems, and assemblies intended to provide shelter and...
<table>
<thead>
<tr>
<th>Version</th>
<th>Energy and Atmosphere (EA)</th>
<th>LEED Version (EA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V3 (2009) and earlier</td>
<td>EA Prerequisite: Fundamental Commissioning</td>
<td>EA Credit: Enhanced Commissioning</td>
</tr>
<tr>
<td></td>
<td>No requirements related to building enclosure (BE)</td>
<td>References NIBS GL3-2012</td>
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<tr>
<td>V4 (2016)</td>
<td>Review of the OPR and BOD relative to BE</td>
<td>2 points for BECx</td>
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<tr>
<td></td>
<td>1 design peer review of BE</td>
<td>Review of BE contractor submittals</td>
</tr>
<tr>
<td></td>
<td>BE requirements to be included in OPR and BOD</td>
<td>2 points for BECx</td>
</tr>
<tr>
<td></td>
<td>Verify operator and occupant training delivery and effectiveness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Verify seasonal testing</td>
<td>Prepare an O&amp;M Plan (including training in CDs)</td>
</tr>
<tr>
<td></td>
<td>Develop on-going Cx plan</td>
<td>Verify operator and occupant training delivery and effectiveness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Verify seasonal testing</td>
</tr>
</tbody>
</table>
Building Enclosure Commissioning (BEC<sub>x</sub>)
2018 NIBS/ASTM/RCI JOINT STATEMENT

Joint statement July 11 announcing their intent to avoid duplication of effort relating to their respective building enclosure commissioning (BEC<sub>x</sub>) programs.

The Institute is rolling out a series of new BEC<sub>x</sub> certificate modules as an education component of an agreement with ASTM to create a joint certificate in building enclosure commissioning. The first three

In addition, RCI Inc., in partnership with Professional Testing, Inc., a certification and examination development company, is developing certifications for the various BEC<sub>x</sub> roles as defined by ASTM. RCI’s goal is to develop full-scope certifications for each area to advance the level of quality and standards across the U.S. BEC<sub>x</sub> industry. These certifications will be developed in accordance with accreditation
Building Enclosure Commissioning (BECx)

CONSULTANT’S ROLE AND FOCUS

• **Primary BECx Tasks by Design Phase**
  – **Pre-Design Phase**: Kick-off meeting, BECx plan, Owner’s Project Requirements (OPR) development
  – **Design Phase**: Peer reviews at SD, DD, and CD
  – **Pre-Construction**: Shop drawing/submittal review, mock-up performance testing, and pre-con meetings
  – **Construction**: Field observation and performance testing
  – **Occupancy**: Post-occupancy walk-through, warranty review/report, and final BECx report
Building Enclosure Commissioning (BECx)

CONSULTANT’S ROLE AND FOCUS

• Major Focus: Transition detailing/tie-ins (water management, heat transfer, air seal/air barrier continuity)
  – Roof-to-exterior wall
  – Cladding system transitions
  – Window jamb/head/sill conditions
Building Enclosure Commissioning (BECx)
CONSULTANT’S ROLE AND FOCUS

3.2 PREPARATION
A. Seal cracks and joints with recommended material and sealant. Clean surfaces of foreign matter detrimental to installation of retarder.

3.3 DETAIL WORK
A. Transition and Through-Wall Flashing Membranes:
   1. Where directed by manufacturer’s written instructions, apply before or after application of membrane. Create a single layer and maintain continuity of the air barrier assembly from top to bottom of structure.
   2. Apply all seams, columns, joints, openings, and penetrations as indicated in detail drawings, overlapping edge seams minimum 2 inches and laps minimum 4 inches.
   3. Use transition membranes to tie into opening frames, spandrel panels, floor intersections and changes in substrates.
   4. Apply in accordance with manufacturer’s instructions, positioning, lapsing, sealing and protecting as required.

3.4 INSTALLATION OF SHEET MEMBRANE
A. Install membrane barrier in accordance with manufacturer’s instructions.
B. Seal end laps and terminations after each day’s work with crimped bead of mastix. Lap sides 2-1/2 inches minimum and ends 8 inches. Stagger and laps.
C. Apply heavy pressure to membrane at top and bottom terminations to assure positive adhesion at edges. Pull membrane firmly and completely, immediately after each sheet is applied.
D. Lap joints over slope substrate in direction of drainage.
E. Work out air bubbles, wrinkles, and fishmats. Firmly press sheet into place without stretching.
F. Seal ends and edges to each other and to adjoining members with fasteners and sealants as required.
G. At wall penetrations carry moisture barrier on both sides of the opening.
H. At openings:
   1. Wrap moisture barrier into openings at walls.
   2. Plane separate piece of moisture barrier.
   3. Start at sill and wrap 12-inch wide strip of barrier on face of sheathing.
   4. Wrap both jambs with crimped bead with laps.
   5. Wrap head and overlap with jambs.
   6. All laps and seaming sealed with approved sealant.
I. Reinforce membrane over joints if required to maintain, whether barrier joints are static or moving.
J. At overhead applications, or on substrates such as OSB or nailable membrane within 2 inches of edge seam; lap successive membrane minimum 2 inches, covering old head.
K. At terminations of vertical surfaces, turn membrane up into register, under-counter flashing, or secure with termination bar.
L. Patch misaligned, or inadequately lapped seams, punctures or other damage with patch of moisture barrier membrane taped 6 inches over edges of damaged area. Seal edges of patch with mastix.

3.5 APPLICATION OF LIQUID MEMBRANE
A. Apply liquid-applied membrane barrier in accordance with manufacturer’s instructions over manufacturers approved primer.
B. Two part product. Mix in strict accordance with manufacturer’s instructions. Mixed product should have uniform color, free of white streaks.
Building Enclosure Commissioning (BEC\textsubscript{x})

CONSULTANT’S ROLE AND FOCUS
What Does the Future Hold?

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