Enclosure Commissioning – a crash course in reality

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RDH Building Science
AIA Quality Assurance

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• Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.
Course Description

• This course will focus the basics of what a building enclosure is and what its intended functions are, and what common test/verification methods used to commission the various functions of the enclosure. Code requirements related to building enclosure commissioning will be discussed, as well as new LEED V4 requirements for enclosure commissioning.
Learning Objectives

1. Identify the primary control layers in enclosure assemblies
2. Define the code requirements for enclosure testing
3. Identify common test procedures for enclosure systems
4. Review the new LEED V4 building enclosure Cx requirements
The Building Enclosure

Fundamentally an environmental separator – distinguishes a building from a structure

• Needs to control:
  • Water
  • Air flow
  • Vapor diffusion
  • Heat flow
  • Light & solar radiation
  • Noise, fire, smoke

• While at the same time:
  • Transfer structural loads
  • Be durable & maintainable
  • Be economical & constructible
  • Look good
How do we commission it?

• What is BECx?

• Fundamentally a QA/QC program to ensure the enclosure design meets OPR, and to ensure the enclosure construction meets the design (and OPR)

• 5 phases:
  • Predesign
  • Design
  • Preconstruction
  • Construction
  • Occupancy & Operations

• Focus more on materials, assemblies, and details

• Functional testing of many performance attributes in the field is difficult
EXECUTIVE SUMMARY

The process of commissioning the enclosure follows a similar process as other building systems. However, commissioning the enclosure differs from commissioning other building systems in the focus on materials and assemblies. The enclosure is designed and field assembled from numerous materials with varying properties. These materials are manufactured by different companies for a specific function, assembled mostly on site one piece at a time by many different tradespeople, working for several different contractors with often minimal coordination. The work is performed in all possible weather conditions with the intention of meeting very well-defined performance criteria. The performance of the enclosure cannot be verified until the entire building is completely enclosed. At this time it is not possible to tune or dial in the performance. To access a nonperforming subsystem or assembly might be very expensive. Thus, the most reliable means to achieve performance targets during construction is to assure that an expert with technical knowledge of the design and installation of the systems being proposed for the building is integrated into the design process and to visually observe the installation of a statistical sampling of the work. Verification testing should be performed throughout the installation of the enclosure subsystems and components.
BECx/Cx Standards & Guides

- 2005: ASHRAE Guideline 0 – Commissioning Process for Buildings & Systems
- 2006: NIBS Guideline 3 – Building Enclosure Commissioning Process
- 2012: ASTM E2813 – Standard Practice for Building Enclosure Commissioning
BECx Phases

- Pre-design
- Design
  - Schematic Design
  - Design Development
  - Construction Documentation
- Pre-Construction
- Construction
- Occupancy & Operations
Predesign - OPR

Need to define expectations:

- Use/occupancy classification, construction type, importance factor
- Minimum service life of the building (maintainable?)
- Geographic location & climate (Zone 4C – mixed marine)
- Anticipated interior conditions (temp, RH, positive/negative pressure)
- Energy use, operational, and performance expectations
- Maintenance constraints – no time loss facility?
- Project delivery method, schedule, budget
- Owner’s risk tolerance for improperly managed heat/air/moisture
- Living Document
Schematic Design

- Basis of Design (BOD) developed by design team
- Records technical concepts, assumptions, calculations, decisions, and product selections used to meet OPR (or other requirements)
- Includes narrative descriptions of enclosure systems (e.g. roof, walls, floors, windows, skylights, etc.)
- Referenced during subsequent review of DD & CD documents
Design Development

• Further development by design team
• Preliminary specifications developed for enclosure products, systems, assemblies, and testing
• Thermal/hygrothermal performance of assemblies/components verified against OPR
• Interface detailing still very preliminary – identify areas of concern
Construction Documents

- All enclosure interface detailing finalized
- All enclosure specifications finalized (including BECx specification)
- Final CDs must be complete and accurate enough to allow for procurement and construction of a building that meets the OPR
Construction Phase

- Review enclosure related RFIs and confirm responses are in line with OPR (and other applicable requirements)
- Review submittals/shop drawings
- Pre-installation meetings
- Mockups (free standing or in-place)
- Review ongoing enclosure construction progress
- Field testing
- Keep logs of action items, test locations & results, remedial work
Construction Phase

- Review submittals/shop drawings
Construction Phase - Mockups

- Could be free standing, in-situ, or even off site
Construction Phase - Testing

- ASTM E2813 Annex A2
- Separates into categories
  - Acoustic performance
  - Air infiltration
  - Thermal performance & condensation resistance
  - Water penetration
  - Durability and appearance
  - Structural performance
  - Rainscreen pressure equalization
  - Solar optical performance
  - Moisture content
  - Security
- Denotes lab testing, field mockup testing, or in-situ field testing
- Two different paths – fundamental & enhanced
Excerpt from Annex A2

<table>
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<th>Property</th>
<th>Standard Designation</th>
<th>Title</th>
<th>Enhanced</th>
<th>Fundamental</th>
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<td>Standard Test Method for Ball Drop Impact of Laminated Architectural Flat Glass</td>
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Most Common BECx Testing

- Water – ASTM E1105, D5957, AAMA 501.2
- Air – ASTM E 779, E1186, E783
- Adhesion – ASTM D4541, C794, C1193
- AAMA 501.4 for unitized glazing
Occupancy and Operations

- Lots of close out documentation
- Completed action item lists
- Compiled test results
- O & M requirements for enclosure systems (mostly cleaning procedures)
- Fully executed warranties
- All compiled into a final report
LEED v4 BECx - Fundamental

- New to V4: BECx included in fundamental commissioning & verification

**REQUIREMENTS**

**Commissioning Process Scope**

Complete the following commissioning (Cx) process activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies, in accordance with ASHRAE Guideline 0-2005 and ASHRAE Guideline 1.1-2007 for HVAC&R Systems, as they relate to energy, water, indoor environmental quality, and durability.

**Requirements for exterior enclosures are limited to inclusion in the owner’s project requirements (OPR) and basis of design (BOD), as well as the review of the OPR, BOD and project design. NIBS Guideline 3-2012 for Exterior Enclosures provides additional guidance.**

- Develop the OPR.
- Develop a BOD.

The commissioning authority (CxA) must do the following:

- Review the OPR, BOD, and project design.
- Develop and implement a Cx plan.
- Confirm incorporation of Cx requirements into the construction documents.
- Develop construction checklists.
- Develop a system test procedure.
LEED v4 BECx - Enhanced

- Enhanced Commissioning (Option 2 – Envelope Commissioning, 2 points)
- Fundamental BECx plus a lot more
- Essentially follows NIBS Guideline 3

<table>
<thead>
<tr>
<th>Phase</th>
<th>Cx task</th>
<th>Responsible party</th>
<th>Cx</th>
<th>Enhanced Cx</th>
<th>MBCx</th>
<th>BECx</th>
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<tbody>
<tr>
<td>Predesign</td>
<td>Change Cx to Enhanced</td>
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<td>Construction Documents</td>
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<tr>
<td>Construction Documents</td>
<td>Include monitoring-based Cx requirements</td>
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<tr>
<td>Construction Documents</td>
<td>Include envelope-based Cx requirements</td>
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<td>Construction Activities</td>
<td>Complete final commissioning report</td>
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<td>Construction Activities</td>
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<td>Occupancy and operations</td>
<td>Complete Cx report</td>
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<td>Occupancy and operations</td>
<td>Compile final systems manual</td>
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<td>Compile final systems manual</td>
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</table>
Does code require any BECx?

• WSEC & SEC requires whole-building air leakage testing (since 2009)
• More on this later…
Enclosure Design 101

• Nature is lazy – 2nd law of thermodynamics (hot to cold)
• Gravity is free – slope to drain
• Flashings are your friends
• Higher exposure demands higher performance
• Good design can overcome poor workmanship, but good workmanship cannot overcome bad design
• It costs many times more to fix it later
• There is no more sustainable building than a durable one
Control Layers

- Water
- Air
- Heat
- Vapor
- Sound
- Fire

Building Form & Features
Water Shedding Surface (WSS)
Water-Resistive Barrier (WRB)
Air Barrier System
Thermal Insulation
Vapor Retarder/Barrier

1 – Water is defined here as precipitation (rain, snow, hail, etc.) and ground water
2 – Vapor is separately defined here as the water vapor in air, as well as condensate moisture
Designing for our climate

- Water is wet…

- Uncontrolled water penetration and condensation make up the vast majority of all construction related claims in the US

- 90% of all water penetration issues occur within 1% of the building surface area (Construction Waterproofing Handbook)
The 4 D’s of rain control

Deflection
- reduce water on the building – building form
- Redirect water away – drip flashings

Drainage
- Provide clear drainage path
- Slope surfaces

Drying
- Allow remaining water to dry

Durability
- Store moisture within materials that have adequate moisture tolerance
Wetting and Drying

- Water gets in (wetting)
Wetting and Drying

• Then dries
Wetting and Drying

How do things dry?

• Diffusion (movement through materials – molecular)
• Evaporation (conversion from liquid to gas at surface)
• Convection (air movement/transport)
• Things dry faster when they are warm & when air is moving past them

How does the wall assembly affect temperature & air movement?
Wetting and Drying

40°F → 70°F
Wetting and Drying

40°F

70°F
Wetting and Drying

40°F

70°F
Wetting and Drying

What has happened to wall systems over the last few decades?

• More insulation
• Building material quality has decreased (OSB, fast growth timber)
• Air tightness has increased
• Occupant comfort expectations have changed
• All of this results in lower tolerance for wetting, as moisture storage capacity decreases and drying capacity decreases
Wetting and Drying

How do we keep the sheathing and other materials dry under these new conditions?

• Don’t let them get as wet, and
• Allow air to move by them to promote drying
Wetting and Drying
Wetting and Drying
Wetting and Drying
Water Control in Walls

Rainscreen as a water penetration control strategy

• Water shedding surface (WSS) is at a different location in the assembly than the water resistive barrier (WRB) and air barrier (AB)

• Capillary break created between the WSS and WRB

• WRB and AB may or may not be at the same location in the assembly, but both must be continuous!
Glazing – Same Principles
Heat/Air/Vapor Control

1 – Water is defined here as precipitation (rain, snow, hail, etc.) and ground water
2 – Vapor is separately defined here as the water vapor in air, as well as condensate moisture
Condensation

- Warm air holds more moisture than cold air (relative humidity)
- Dew point = temp at which vapor starts to condense out of the air (depends on RH)
- If air contacts a surface that is below the dew point it will cool and deposit liquid water (condensation)
- Keep warm air away from your cold beer
Vapor Transport

Vapor diffusion
• Through 100sf wall
• @20 perm = 4 tsp/hr

Air transport
• Through 100sf wall
• @18 L/s (approx)
• 2.4 ACH in 1000 cf room
• =48 tsp (1 cup)/hr
Air Barrier vs Vapor Retarder

Vapor Retarder
• Controls flow of moisture by diffusion, nothing more
• Location within assembly is climate specific (not always needed)

Air barrier
• Controls flow of moisture (in a fundamentally different way)
• Controls flow of heat
• Controls sound
• Controls flow of contaminants (smoke, pollutants)
• Could also be a vapor retarder
• Could also be a water resistive barrier
What about insulation?

• You can’t stop heat flow, you can only slow it down
• “Don’t eat your sweater” – Joe Lstiburek
• Benefits of exterior insulation
  • Keeps structure warm (less thermal cycling)
  • More bang for your buck (less thermal bridging)
  • Moves dew point out of moisture sensitive areas
• The “perfect wall”:
  • Cladding – protects other layers, aesthetics
  • Air space – provides ventilation & drainage
  • Insulation – mineral fiber typically
  • WRB/AB/VR – Can be 1 product
  • Backup wall – services, finishes
Roofing/Waterproofing

• Start with your structure – metal? Concrete? Wood?
• How do you get slope?
• How do you attach your assembly? (adhered, attached, ballasted)
• Conventional? Inverted? Vented?
• Membrane options – single ply, 2/3 ply, welded, torched, hot mopped, cold adhesive
• Overburden - Pavers? Green roof? Topping slab?
Conventional Roof

- Water barrier
- Thermal barrier
- Air/vapor barrier
Inverted Roof

- Ballast
- Thermal barrier
- Drainage plane
- Water/vapor/air barrier
- It’s the perfect wall on its side!
Vented Roof

- Water barrier
- Thermal barrier
- Vapor/air barrier
Vented low-slope roofs

Re-Thinking Ventilated Attics: How to Stop Mold Growth in Coastal Climates

Posted on April 07, 2015

Written by Marcus Dell

Marcus Dell
Marcus is a professional engineer who specializes in practical solutions to building enclosure problems.
Enclosure Design Review 101

- Continuity check
- Every plan, every section, every detail
- Air barrier boundary must be identified in construction docs (WSEC)
Not always simple
Always a system

Materials  Components  Accessories

Whole Building
Where trades come together
Looks good on paper...
Need to think in 3D
Air Barrier Testing

- Materials, assemblies, and components (lab)
- Mockups (qualitative, work through tricky details)
- Suites (LEED ETS)
- Whole building (WSEC/SEC) – a “report card” for the enclosure
Air Barrier Testing

- Airflow in = airflow out
Air barriers - not a new concept

The Manufacturer and Builder.

Paper as a Building Material.

We were not mistaken when we predicted a bright future for the business of furnishing to the building trade a kind of paper adapted as a substitute for wood, stone, and plaster. A trial of nearly five years has settled this matter and rendered it unnecessary to enter into any extended details in regard to its advantages and importance in the construction of buildings. It is peting. Finally, an estimate of cost, showing that a house of 16 by 22 feet, and 14 feet high, may be entirely covered on four sides for less than $10; and one of 24 by 36 feet, and 20 feet high, for less than $25. The perfect tightness of the walls and non-conductibility of the material causes a saving in fuel, which for a single season is claimed to be considerably less than the above sums.

It is one of the triumphs of modern practical science to place the comforts formerly only enjoyed by the rich within the reach of the greatest possible number. Paper houses, thus far looked down upon as worthless, are destined in the future to become the favorite abodes of those who want to enjoy comfort, notwithstanding possessed of small means.

Serial: The Manufacturer and Builder Volume 0006 Issue 2 (February 1874)
Title: Paper as a Building Material [pp. 32-33]
Closing thoughts

- LEED v4 fundamental BECx could hardly be called commissioning
- LEED v4 enhanced BECx (NIBS GL3) is a huge step up, but could use more clarity (new ASTM standard provides this)
- Enclosures separate one environment from another – need to have a thorough understanding of both environments to design successfully
- When in doubt, stick to fundamentals
- It’s not the details you have that get you in trouble, it’s the details you don’t have – try to look ahead during construction
- Air barriers are not going anywhere, and for good reason
Thank You

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