Envelope Commissioning
USG FOC 2017

October 26, 2017
John Jefferson, RA, PMP
Darren Draper, PE, CxA

BOARD OF REGENTS OF THE UNIVERSITY SYSTEM OF GEORGIA

Commissioning Process

Most project teams are familiar with the concepts of Systems Commissioning, especially as required for LEED certification

- Third party verification of performance
- Energy optimization balanced with occupant comfort
- Design reviews for maintainability
- Construction observation and installation verification
- Functional performance testing
- Owner training

Learning Objectives

Recognize the steps in the Envelope Commissioning (BECx) process.

Recognize the value of the BECx process to the various stakeholders of the project team.

Recognize BECx's value to high performance, sustainable buildings.

Recognize some of the testing techniques used in the BECx process.

Analyze real world project examples from design through construction phases demonstrating the benefits of BECx.

BECx Energy Considerations

New requirements for enclosure for energy:

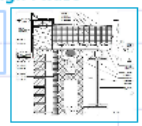
- Requirement for a continuous air barrier
  - Barrier must extend over ALL envelope surfaces
  - All joints, penetrations must be detailed on design documents
- Cool Roofs are required for Climate Zones 1 to 3
  - Improved solar reflectance
  - Increased insulation requirements
- Glazing limitations
  - Window-Wall Ratio ≤ 40% of gross wall area
  - Major changes to SHGC requirements over 90.1-2007

BECx Process - Design Phase

Similar to Systems Commissioning, BECx is the third-party process of reviewing the design and construction of envelope

Design Phase Steps:

- Creation/Review of Owner's Project Requirements (OPR) and designer's Basis of Design (BOD)
- Commissioning Kick-Off Meeting
- Commissioning Plan
- Design Document Reviews
- Commissioning Specifications including Envelope/ Mock-Up Testing Specifications
- Development of Installation Checklists



BECx Design Reviews

Focus of design review for envelope (waterproofing, dampproofing, vapor barrier, air barrier, insulation, roofing, sealants, glazing):

- Continuity of waterproofing, thermal insulation, and air barriers
  - Attention focused on completeness of details
  - Interaction of differing materials for assemblies
- Potential points of failure
- Constructability
- Maintainability
- Energy performance and sustainability

BECx - Post Construction

The Post-Construction Phase of the Envelope Commissioning process includes:

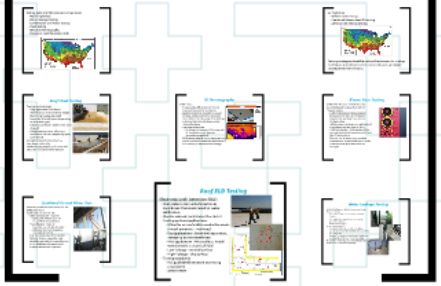
- Envelope Substantial Completion Review
- O&M Staff Training
- Envelope Maintenance Recommendations
- Commissioning Report
- 10 Month Warranty Review

BECx - Construction Phase

The Construction Phase of the BECx process includes:

- Submittal and Shop Drawing Reviews
- Commissioning Meetings
- Pre-Enclosure/Mock-Up Meetings with the various envelope subcontracting trades to set clear expectations and responsibilities
- Site Observations
- Mock-Up Construction/Testing
- Envelope Testing
  - Water Spray Testing
  - Combined Air/Water Testing
  - Pulse Testing
  - Infrared Thermography
  - Combined IR and Blower Door Testing

Envelope Testing



BECx Benefits and Costs

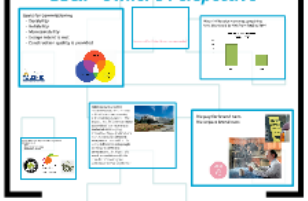
Case Studies

What is Commissioning?

Commissioning is an offspring of the nautical tradition of commissioning all of the systems on a sea-going vessel to make sure they are functional before it sets sail

Commissioning is a systematic process, led by a Commissioning Agent (CxA), of ensuring that all building systems perform interactively according to the design intent and the Owner's operational needs

BECx - Owner's Perspective



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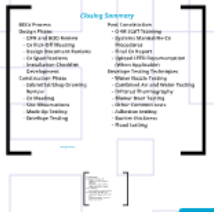

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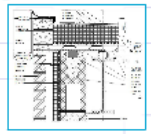

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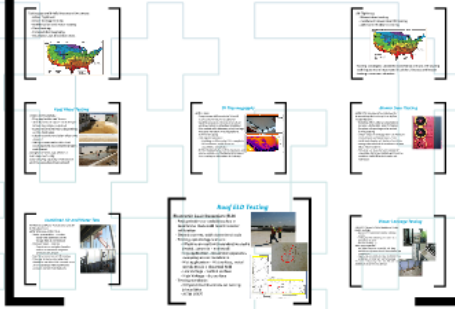

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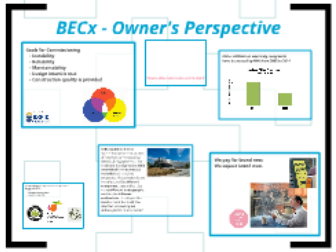

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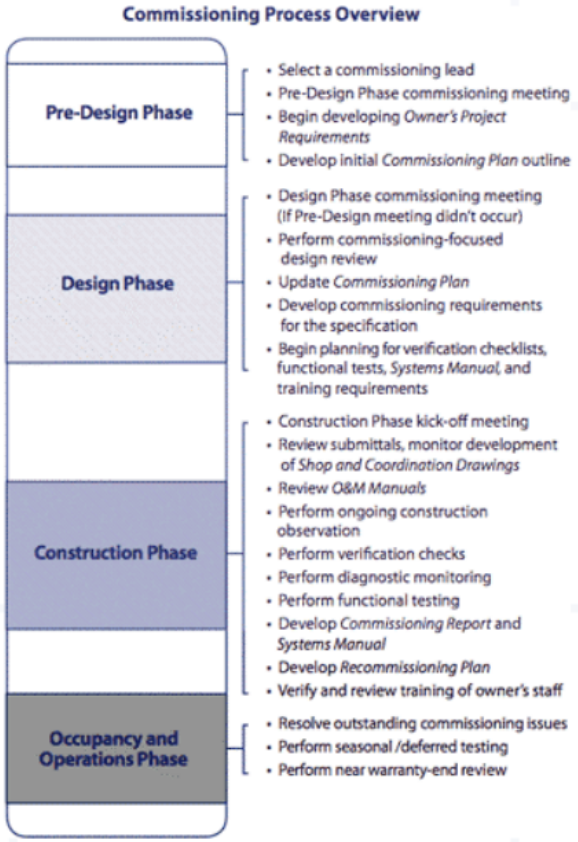

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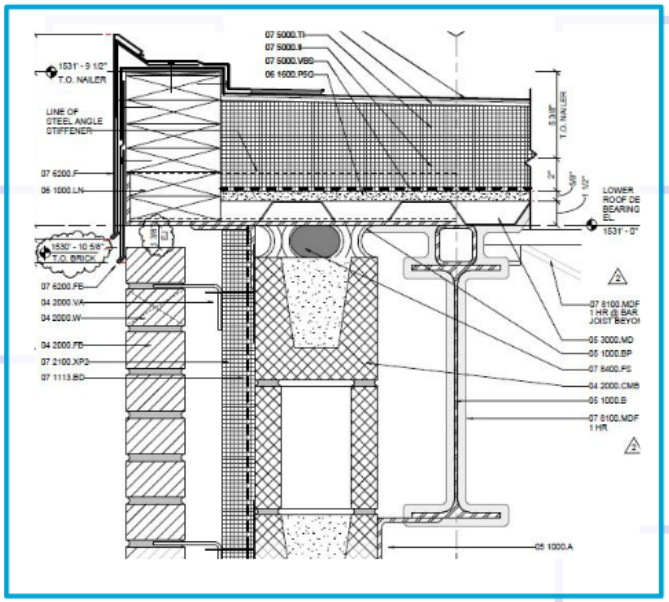

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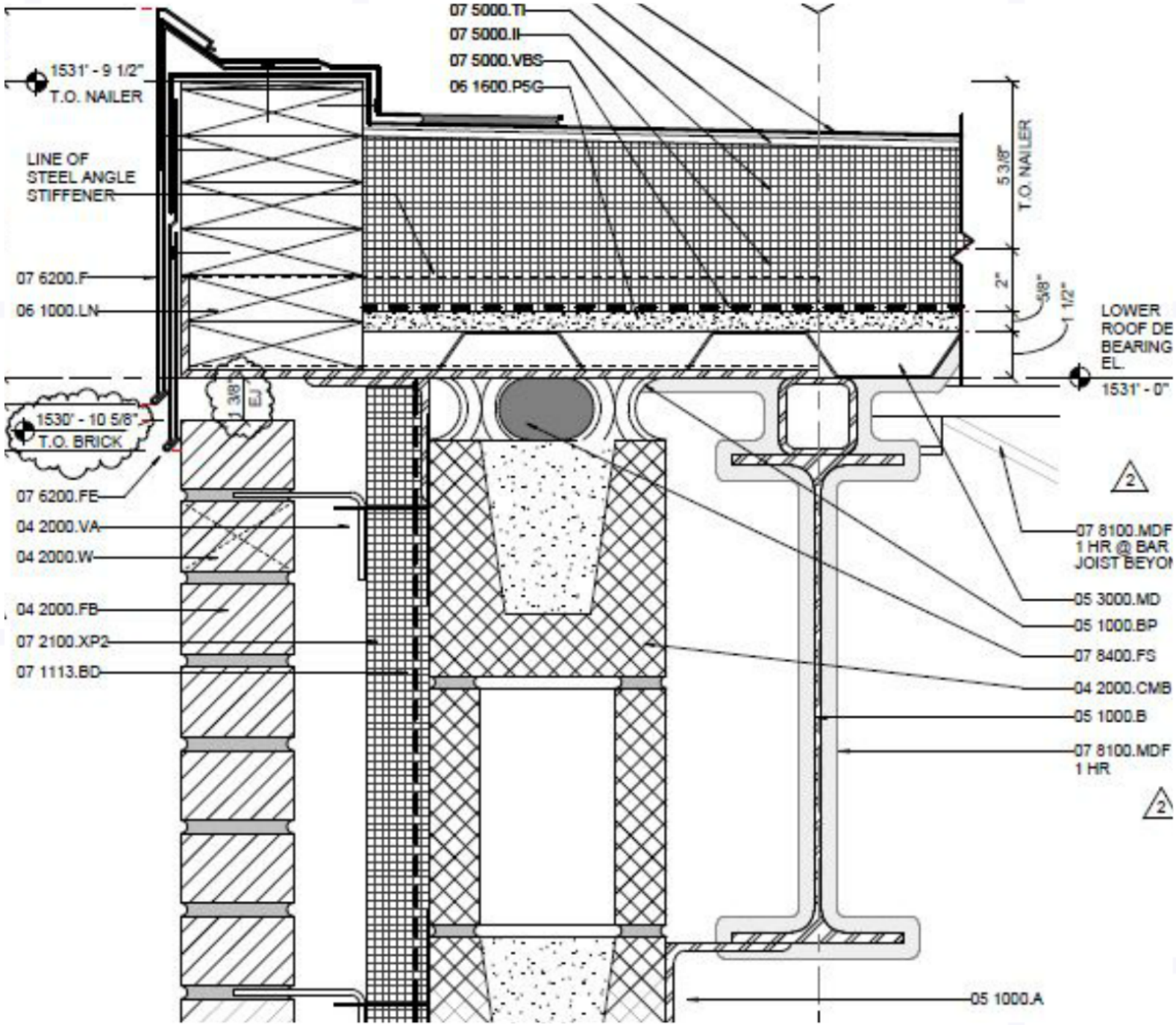
1531' - 9 1/2"
T.O. NAILER
LINE OF
STEEL ANGLE
STIFFENER
07 6200.F
06 1000.LN
1530' - 10 5/8"
T.O. BRICK
1 3/8"
EJ
07 6200.FE
04 2000.VA
04 2000.W
04 2000.FB
07 2100.XP2
07 1113.BD
07 5000.TI
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07 5000.VBS
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LOWER
ROOF DE
BEARING
EL.
1531' - 0"
2
07 8100.MDF
1 HR @ BAR
JOIST BEYO
05 3000.MD
05 1000.BP
07 8400.FS
04 2000.CMB
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2
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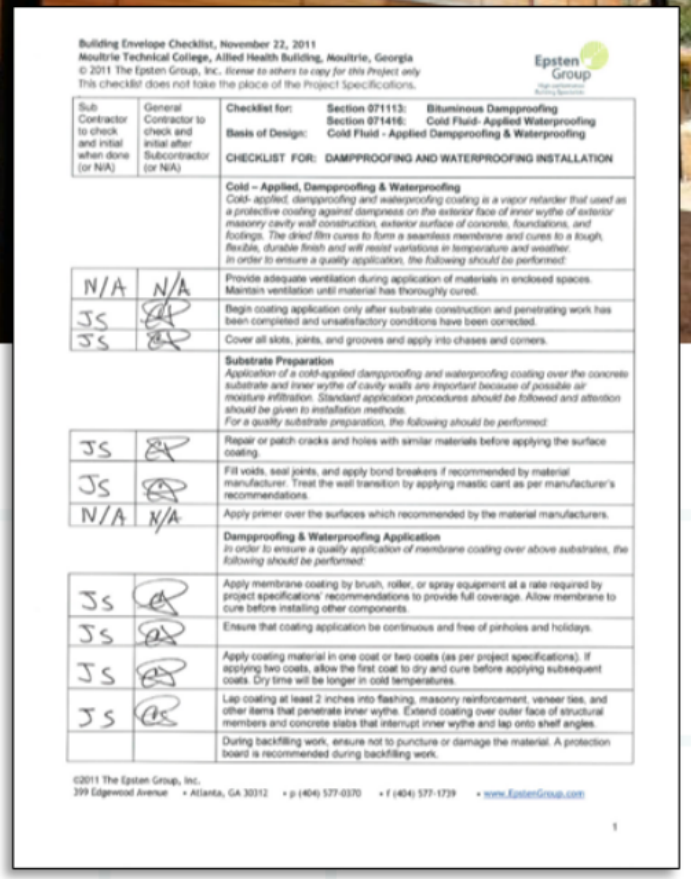

Building Envelope Checklist, November 22, 2011
Moultrie Technical College, Allied Health Building, Moultrie, Georgia
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This checklist does not take the place of the Project Specifications.

Epsten Group

Sub Contractor to check and initial when done (or N/A)	General Contractor to check and initial after Subcontractor (or N/A)	
		Checklist for: Section 071113: Bituminous Dampproofing Section 071416: Cold Fluid- Applied Waterproofing **Basis of Design:** Cold Fluid - Applied Dampproofing & Waterproofing **CHECKLIST FOR: DAMPPROOFING AND WATERPROOFING INSTALLATION**
		Cold – Applied, Dampproofing & Waterproofing *Cold- applied, dampproofing and waterproofing coating is a vapor retarder that used as a protective coating against dampness on the exterior face of inner wythe of exterior masonry cavity wall construction, exterior surface of concrete, foundations, and footings. The dried film cures to form a seamless membrane and cures to a tough, flexible, durable finish and will resist variations in temperature and weather.* *In order to ensure a quality application, the following should be performed:*
N/A	N/A	Provide adequate ventilation during application of materials in enclosed spaces. Maintain ventilation until material has thoroughly cured.
JS		Begin coating application only after substrate construction and penetrating work has been completed and unsatisfactory conditions have been corrected.
JS		Cover all slots, joints, and grooves and apply into chases and corners.
		Substrate Preparation *Application of a cold-applied dampproofing and waterproofing coating over the concrete substrate and inner wythe of cavity walls are important because of possible air moisture infiltration. Standard application procedures should be followed and attention should be given to installation methods.* *For a quality substrate preparation, the following should be performed:*
JS		Repair or patch cracks and holes with similar materials before applying the surface coating.
JS		Fill voids, seal joints, and apply bond breakers if recommended by material manufacturer. Treat the wall transition by applying mastic cant as per manufacturer's recommendations.
N/A	N/A	Apply primer over the surfaces which recommended by the material manufacturers.
		Dampproofing & Waterproofing Application *In order to ensure a quality application of membrane coating over above substrates, the following should be performed:*
JS		Apply membrane coating by brush, roller, or spray equipment at a rate required by project specifications' recommendations to provide full coverage. Allow membrane to cure before installing other components.
JS		Ensure that coating application be continuous and free of pinholes and holidays.
JS		Apply coating material in one coat or two coats (as per project specifications). If applying two coats, allow the first coat to dry and cure before applying subsequent coats. Dry time will be longer in cold temperatures.
JS		Lap coating at least 2 inches into flashing, masonry reinforcement, veneer ties, and other items that penetrate inner wythe. Extend coating over outer face of structural members and concrete slabs that interrupt inner wythe and lap onto shelf angles.
		During backfilling work, ensure not to puncture or damage the material. A protection board is recommended during backfilling work.

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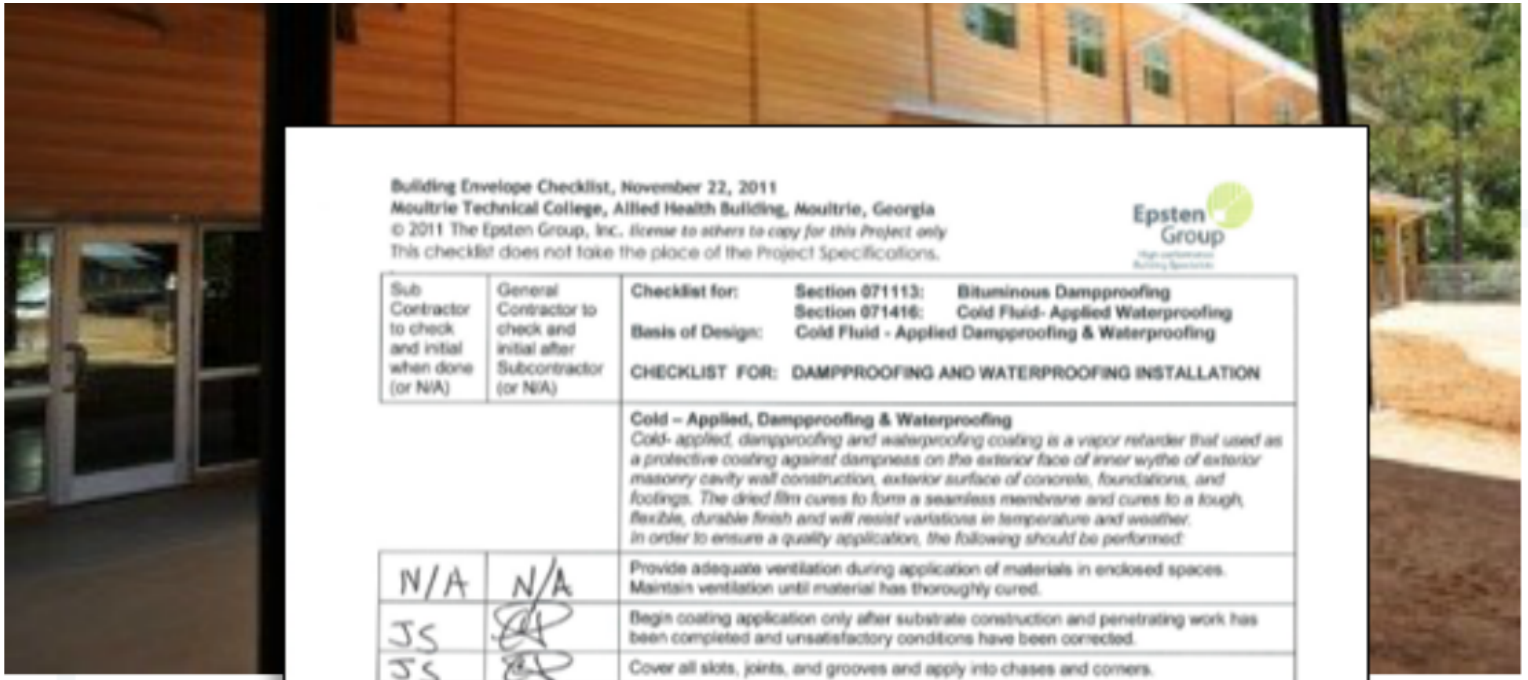

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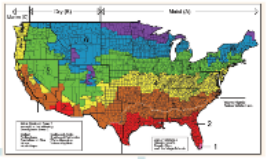
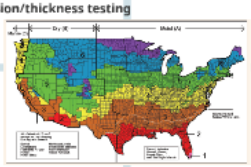
Envelope Testing

Testing generally falls into one of two areas:
- Water Tightness
- Water leakage testing
- Combined air and water testing
- Flood testing
- Infrared thermography
- Electronic Leak Detection (ELD)



Air Tightness
- Blower door testing
- Combined blower door/IR testing
- Adhesion/thickness testing



Testing strategies should be tailored to climate. Air testing techniques more important in colder climates and water testing in warmer climates

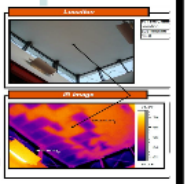
Roof Flood Testing

Testing methodology:
- Plug applicable roof drains
- Add water to 2" above drain height (damming maybe required)
- Leave for 24 to 48 hours (depending on the deck type)
- Observe conditions below after time elapsed
- Safely remove water after test conclusion (do not completely open roof drains)

Straight forward, cost effective
Low slope roofs only
Load-carrying capacity of structural MUST be considered beforehand

IR Thermography

ASTM C1060:
- Temperature differential of 12 to 18 degrees from interior to exterior
- Specific procedure intended to reveal missing, failed or defective insulation
- Also assists with discovery of air leakage, moisture intrusion, missing sealant, thermal bridging
- Testing prerequisites
  - Building is effectively 100% complete
  - All insulation, walls, exterior assemblies completed
- IR Thermography is very inexpensive and can be combined effectively with blower door testing to determine air leakage.



Blower Door Testing

ASTM E779 (Standard Test Method for Determining Air Leakage Rate by Fan Pressurization):
- Building differential pressurization between 25 Pascals and 75 Pascals
- Requires all openings to be sealed during testing
- USACE requires leakage rate ≤ 0.25cfm/sf of enclosure surface area at 75 Pa
- LEED Multifamily: ≤ 0.25cfm/sf at 50 Pa
- Georgia Residential Amendment to 2009 IECC: 7 ACH at 50 Pa
- This test can become very complex/ expensive for larger buildings. It can be combined with IR to determine air leakages.

Combined Air and Water Test

AAMA 503.03 (Water Penetration and Air Infiltration Test):
ASTM E783 and ASTM E1105
- Water penetration – exterior
  - Spray rack assembly on lift
  - 5.0 gal/ft2h at a minimum
- Pressurization – interior
  - Construct an airtight chamber
  - Induce a minimum negative pressure of 6.24 psf
- Test for a minimum of 15 minutes
- This test is more expensive, but should be considered in coastal areas or for buildings with significant/ complex curtain wall systems.

Roof ELD Testing

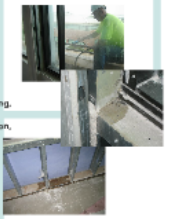
Electronic Leak Detection (ELD)
- Find pinhole-size voids/breaches in membrane that could result in water infiltration
- Electric current, void closes the circuit
- Testing options/applications
  - Effective on roofs with conductive decks (metal, concrete – not wood)
  - Dry application – Grounded apparatus, sweeping across membrane
  - Wet application – Wet surface, metal wands inside a electrical field
  - Low Voltage – wetted surface
  - High Voltage – dry surface
- Testing standards
  - RCI published literature on testing procedures
  - ASTM D7877

Water Leakage Testing

AAMA 501 (Dynamic Water Resistance, Water Nozzle Testing):
- Spray at 12" from most exterior window surface
- Testing for five minutes per section in a prescribed pattern
- Bottom working up

Testing prerequisites
- Completed exterior assembly including sealant and adjacent details (metal paneling, masonry, etc.)
- Exposed areas on interior (no wall insulation, no drywall, no finished floor/carpeting)

This test is very inexpensive and effective for smaller, more common openings.



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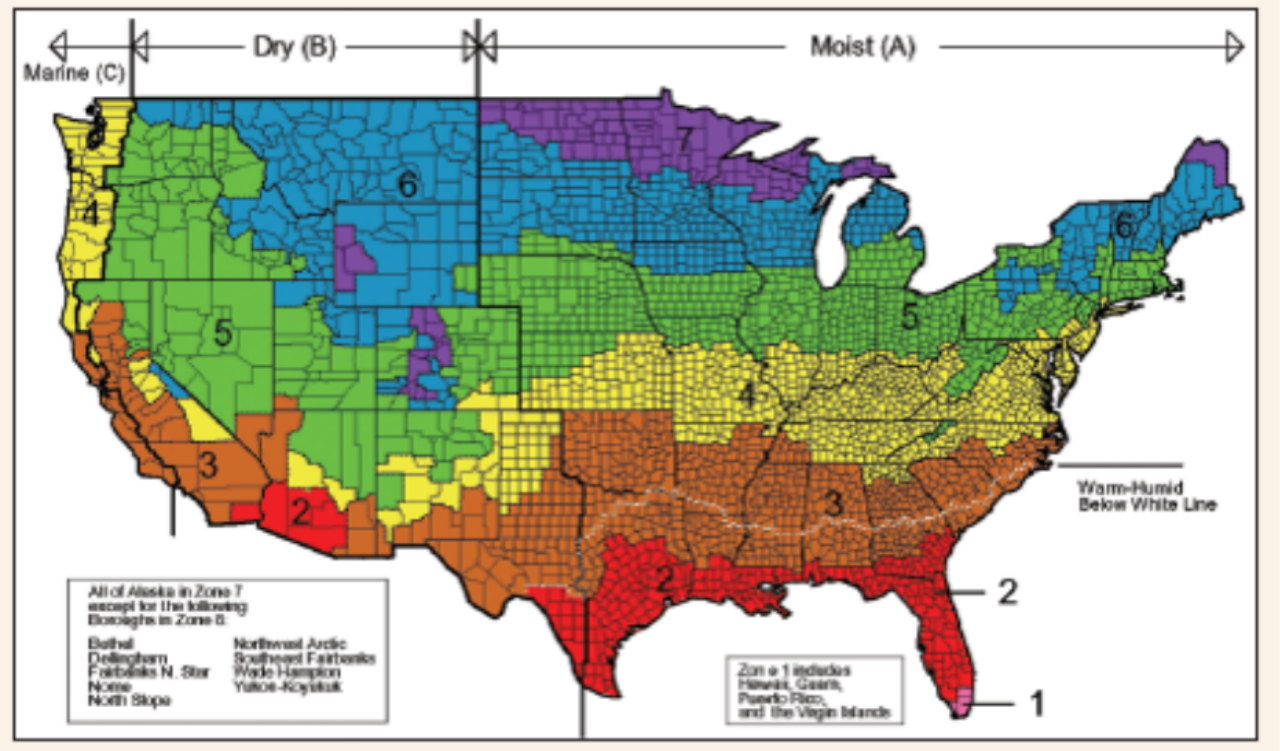

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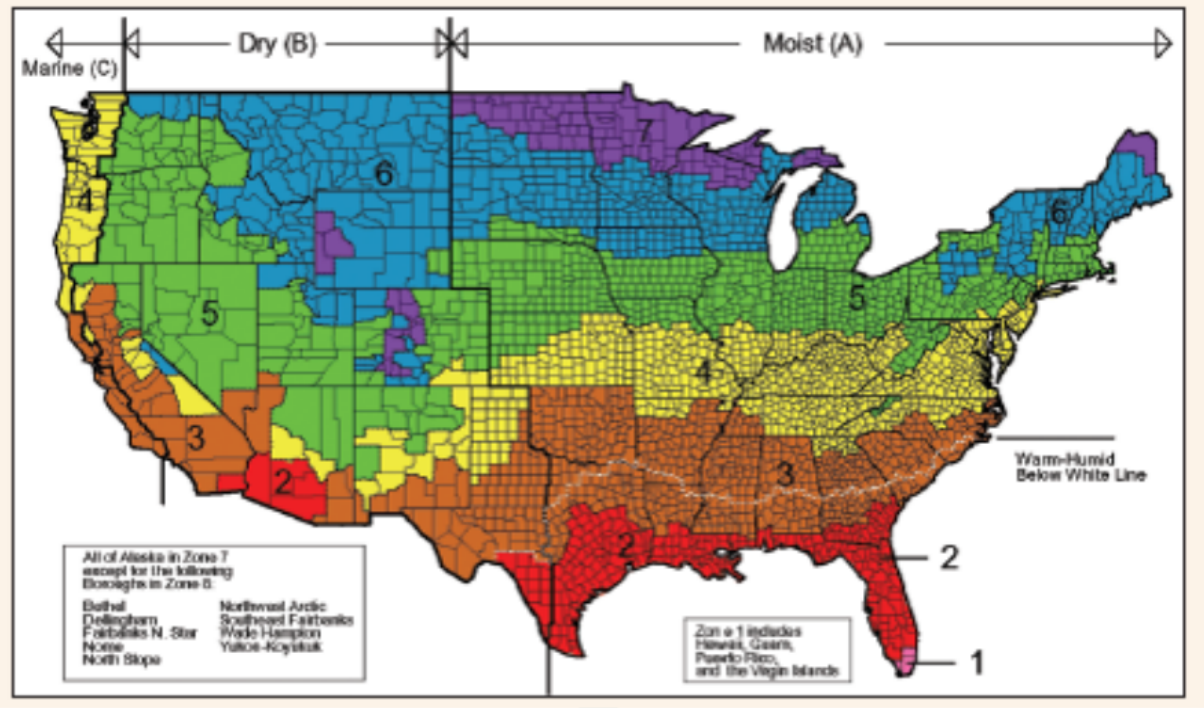

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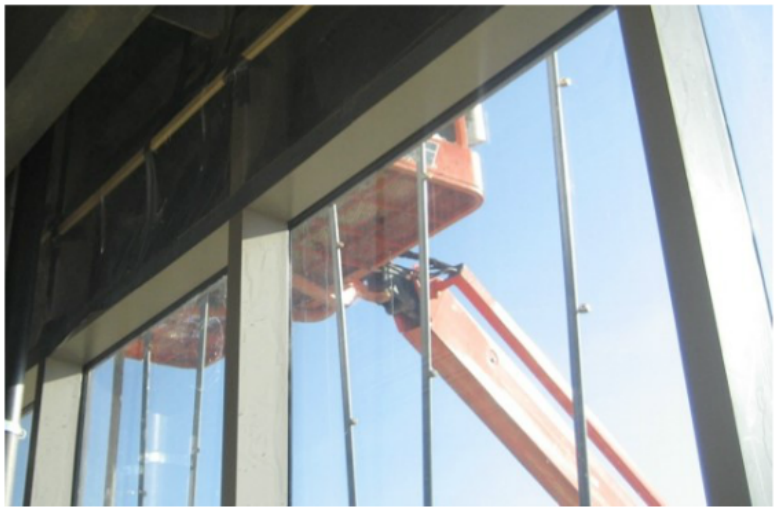

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Testing methodology:

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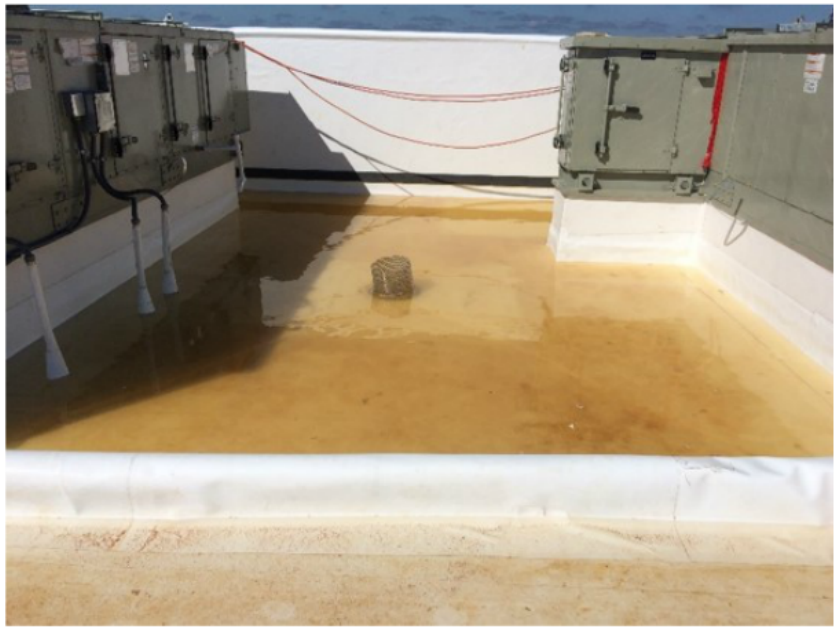
- **Add water to 2” above drain height (damming maybe required)**
- **Leave for 24 to 48 hours (depending on the deck type)**
- **Observe conditions below after time elapsed**
- **Safely remove water after test conclusion (do not completely open roof drains)**

Straight forward, cost effective

Low slope roofs only

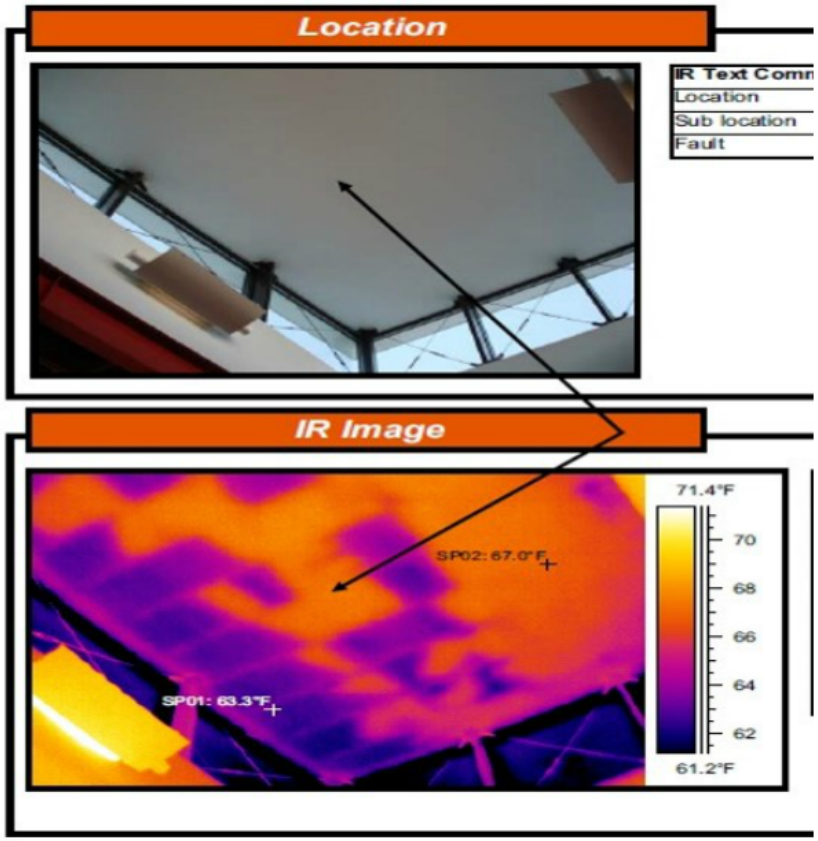
Load-carrying capacity of structural MUST be considered beforehand



IR Thermography

ASTM C1060:

- Temperature differential of 12 to 18 degrees from interior to exterior
- Specific procedure intended to reveal missing, failed or defective insulation
- Also assists with discovery of air leakage, moisture intrusion, missing sealant, thermal bridging
- Testing prerequisites
  - Building is effectively 100% complete
  - All insulation, walls, exterior assemblies completed
- IR Thermography is very inexpensive and can be combined effectively with blower door testing to determine air leakage.



Blower Door Testing

ASTM E779 (Standard Test Method for Determining Air Leakage Rate by Fan Pressurization):

- **Building differential pressurization between 25 Pascals and 75 Pascals**
- **Requires all openings to be sealed during testing**
- **USACE requires leakage rate ≤ 0.25cfm/sf of enclosure surface area at 75 Pa**
- **LEED Multifamily: ≤ 0.25cfm/sf at 50 Pa**
- **Georgia Residential Amendment to 2009 IECC: 7 ACH at 50 Pa**
- **This test can become very complex/ expensive for larger buildings. It can be combined with IR to determine air leakages.**

Roof ELD Testing

Electronic Leak Detection (ELD)

- Find pinhole-size voids/breaches in membrane that could result in water infiltration
- Electric current, void closes the circuit
- Testing options/applications
  - Effective on roofs with conductive decks (metal, concrete – not wood)
  - Dry application – Grounded apparatus, sweeping across membrane
  - Wet application – Wet surface, metal wands inside a electrical field
  - Low Voltage – wetted surface
  - High Voltage – dry surface
- Testing standards
  - RCI published literature on testing procedures
  - ASTM D7877

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BECx - Post Construction

The Post-Construction Phase of the Envelope Commissioning process includes:

- **Envelope Substantial Completion Review**
- **O&M Staff Training**
- **Envelope Maintenance Recommendations**
- **Commissioning Report**
- **10 Month Warranty Review**

BECx Benefits and Costs

Sustainability

Envelope Cx helps project teams provide more sustainable buildings:

- Energy Performance: Continuity of thermal insulation and air barriers and validating through site observation and testing, the envelope performs as intended from an energy standpoint
- Durability and Maintenance: Promote longevity of building envelopes by emphasizing smart detailing and identifying and correcting durability problems during design and construction
- IEQ: Promoting water and vapor tightness, BECx helps prevent mold and other IAQ problems
- Georgia Peach: Though not a specific requirement of the rating system, Envelope Cx has become common practice for State of GA projects

The Georgia Peach

Green Building Rating System:
Energy Efficiency and Sustainable Construction Standards for State Buildings

Costs

The cost of BECx will vary based on the size, complexity, location, testing methods, and CA process.

- $0.25 - $0.75 per square foot is a good range to consider
- Compare to $0.40 - $1.00 per square foot for Systems Commissioning

Compare these costs to the cost of disrupted operations caused by water infiltration and remediation efforts.

- Unlike HVAC systems, which can often be repaired with minimal disruption to operations, faulty wall and window systems often lead to shutting down sections of a facility while repair operations take place

Project Team Member Benefits

Design Team:

- Added quality control in waterproofing details
- Added layer of Construction Administration quality control

Contractor:

- Fewer callbacks after project completion

Owner:

- Verification of air tightness and insulation continuity helps decrease energy costs
- Increased building durability and lower maintenance costs

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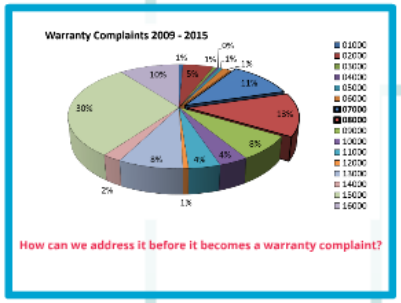
BECx - Owner's Perspective

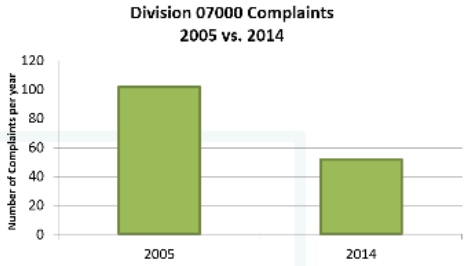
Goals for Commissioning

- Durability
- Reliability
- Maintainability
- Design intent is met
- Construction quality is provided

Georgia State Financing & Investment Commission
GSFIC
BUILDING GEORGIA'S FUTURE



Water infiltration warranty complaints have decreased by 49% from 2005 to 2014



NIBS Guideline 3-2012
"Commissioning the enclosure differs from commissioning other building systems ... The enclosure is designed and **field assembled** from **numerous materials** with varying properties. These materials are manufactured by **different companies**... assembled ...by many **different tradespeople**, working for **different contractors** ... in all possible weather conditions with the intention of meeting well defined performance criteria."

How did Building Envelope Commissioning become a standard at GSFIC?
- LEED
- Historical warranty issues
- Reactive vs. Proactive

The Georgia Peach

We pay for brand new.
We expect brand new.

Brand New With Tags

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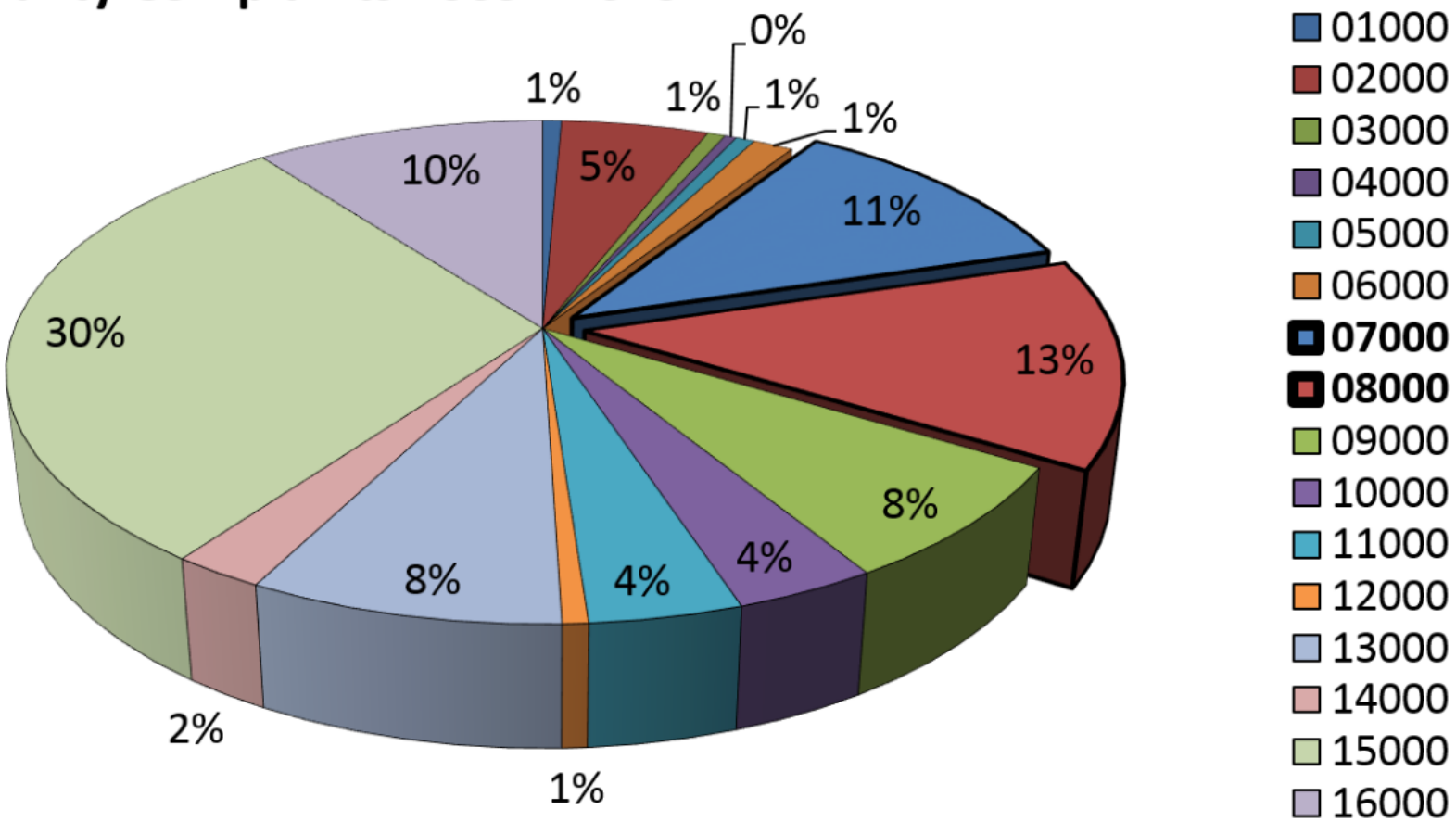
Warranty Complaints 2009 - 2015



How can we address it before it becomes a warranty complaint?

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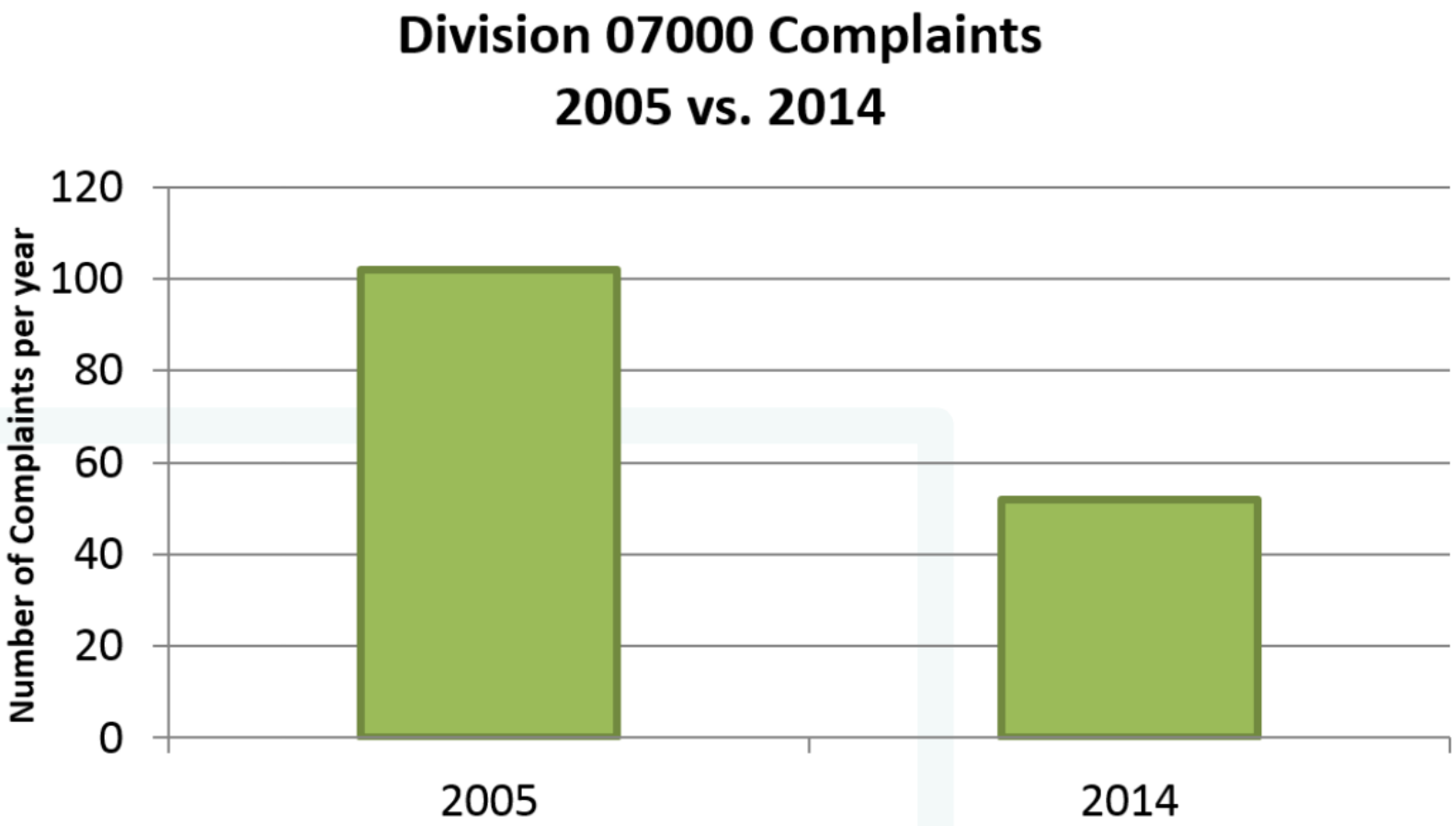


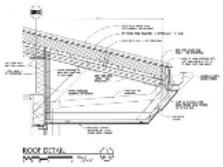
Case Studies

Tech College – South Georgia
College – Metro Atlanta
College – North Georgia
Private College Library – Metro Atlanta

Case Study #1

Envelope Cx was conducted on the Technical College in South Georgia

- Good cooperation with Cx across the design team
- In design review, found several items including:
  - Downspout and gutter detailing
  - Wall flashing and weeps at brick arches and ACM panels
  - Insulation continuity at 2nd floor slab
  - Roof to wall flashing details
  - Warranty specifications



Case Study #1

Construction Phase BECx

- Site Observations
  - Damage to ice and water shield at roof ridge during construction
- Envelope Testing
  - Insufficient sealing of 1st floor windows and failed sealant adhesion tests
  - Water testing showed leakage under the wall and at the storefront system sill at the 2nd floor balcony
- Additional Efforts
  - Post-Construction review led to discovery of improperly installed window/wall assembly
  - Gutter venting system consideration

Case Study #3

35,000 square foot renovation project in 2010 including replacement of windows.

- Epsten Group was contracted in late 2012 to conduct investigation, Infrared Testing and Water Testing on newly installed window assemblies
- Water Testing revealed majority of replaced windows were leaking due to lack of drainage plane beyond brick veneer wall
- Additionally, a lack of flashing and insufficient sealant at existing window assemblies
- Infrared Testing revealed location of water infiltration as well as lack of air tightness

Case Study #2

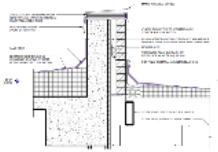
Numerous issues found during construction:

- Waterproofing left exposed for extended duration without backfill – resulting in excessive blistering and unbonding
- Water penetrating under installed roofing system (concrete deck, tapered insulation, modified bitumen cap sheet)
- Water Testing was initially planned for selected units as a sample, but testing immediately led to discovery of water infiltration into window unit through the masonry to window joint.
  - As a result of numerous failures, 100% testing was undertaken until all windows passed

Case Study #2

Extensive BECx activities were requested by GSFIC for this project in addition to MEP systems commissioning. Design phase activities were very productive working with the Architect, including:

- Established requirements for a mock-up
- Setting strong testing requirements including water testing, air/water testing, flood testing, adhesion testing, air barrier thickness testing.
- Main Design Review findings included:
  - Lack of air barrier continuity at certain transitions/locations
  - Minor issues involving roofing details
  - Curtain wall assembly flashing



Case Study #3

- Based on Epsten Group findings and recommendations:
  - Existing brick walls were removed entirely from 3 elevations
  - New air barrier and waterproofing installed
  - Drainage plane with flexible flashing installed
- Ideally the BECx process would have been engaged from Design through Construction, the problems could have been diagnosed before project turnover with no disruption to building operations.

Case Study #4

Epsten Group performed both systems commissioning, architectural improvements:

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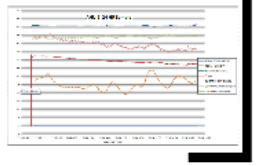
- Testing to verify system performance with tight control requirements.



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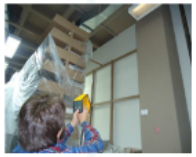

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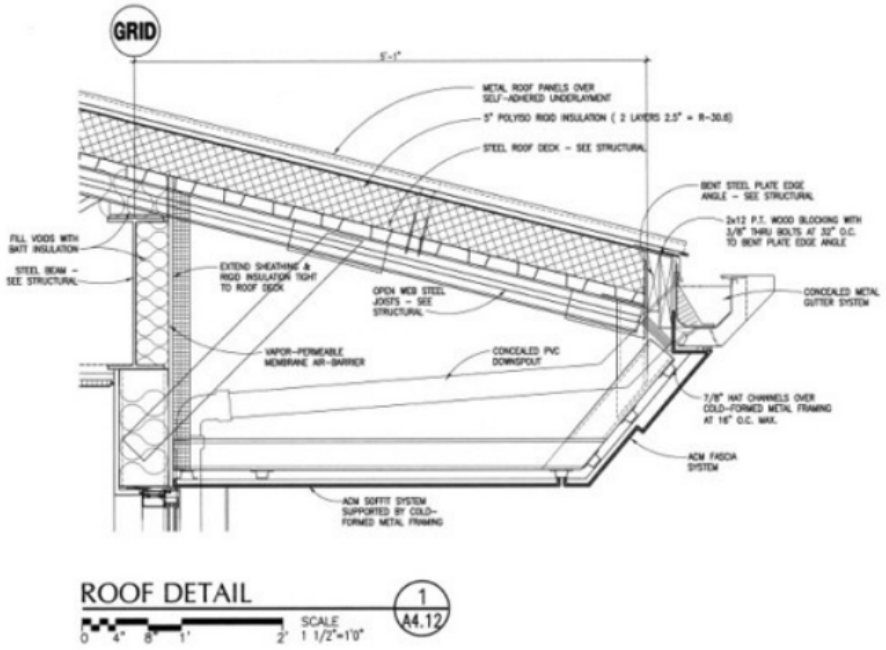

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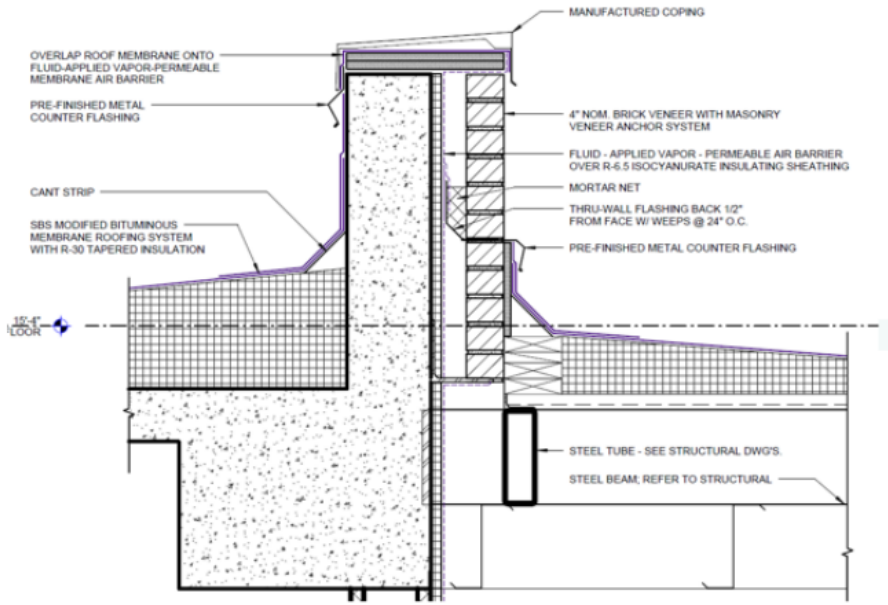

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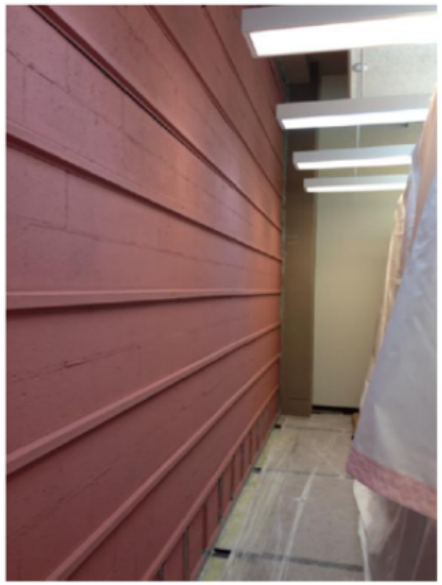
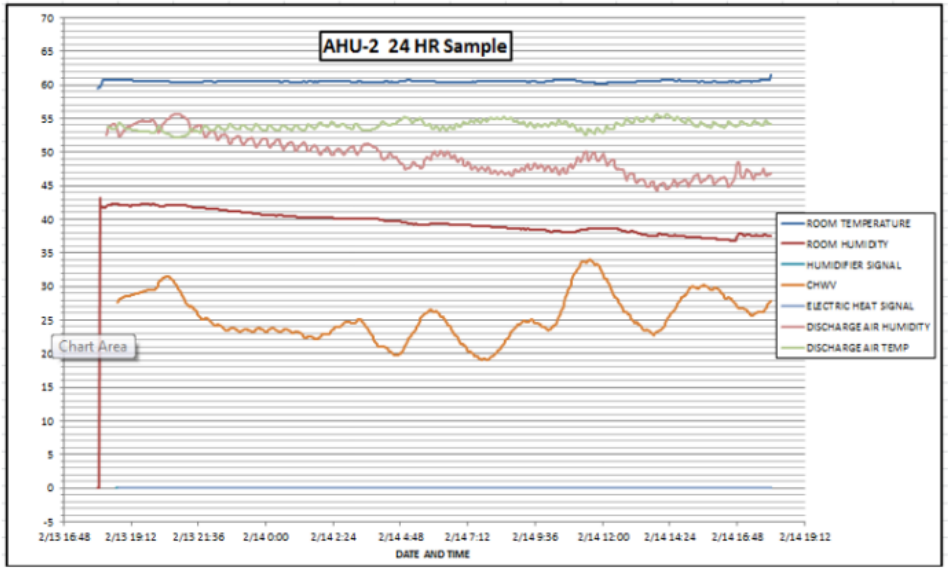


Applying vapor barrier to Room #1

Insulation and drywall applied to Room #1



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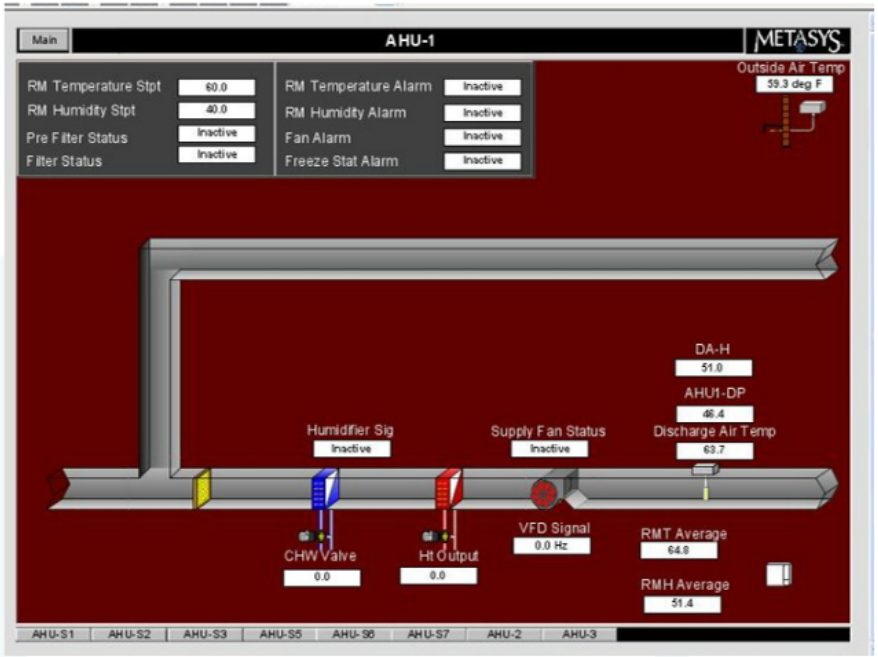


Closing Summary

BECx Process

Design Phase:

- OPR and BOD Review
- Cx Kick-Off Meeting
- Design Document Reviews
- Cx Specifications
- Installation Checklist Development

Construction Phase

- Submittal/Shop Drawing Review
- Cx Meeting
- Site Observations
- Mock-Up Testing
- Envelope Testing

Post Construction

- O+M Staff Training
- Systems Manual/Re-Cx Procedures
- Final Cx Report
- Upload LEED Documentation (When Applicable)

Envelope Testing Techniques

- Water Nozzle Testing
- Combined Air and Water Testing
- Infrared Thermography
- Blower Door Testing
- Other Common tests
- Adhesion testing
- Barrier thickness
- Flood testing

Benefits of BECx

For Design Professionals:

- Improved Quality Control in detailing
- Improved Quality Control in Construction Administration

For Contractors:

- Fewer callbacks after completion

For Owners/Facility Managers:

- Improved energy performance/ cost
- Improved durability and lower maintenance costs

Envelope Commissioning
USG FOC 2017

October 26, 2017

John Jefferson, RA, PMP
Darren Draper, PE, CxA

BOARD OF REGENTS OF THE UNIVERSITY SYSTEM OF GEORGIA

Commissioning Process

Most project teams are familiar with the concepts of Systems Commissioning, especially as required for LEED certification

- Third party verification of performance
- Energy optimization balanced with occupant comfort
- Design reviews for maintainability
- Construction observation and installation verification
- Functional performance testing
- Owner training

Learning Objectives

Recognize the steps in the Envelope Commissioning (BECx) process.

Recognize the value of the BECx process to the various stakeholders of the project team.

Recognize BECx's value to high performance, sustainable buildings.

Recognize some of the testing techniques used in the BECx process.

Analyze real world project examples from design through construction phases demonstrating the benefits of BECx.

BECx Energy Considerations

New requirements for enclosure for energy:

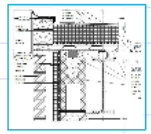
- Requirement for a continuous air barrier
  - Barrier must extend over ALL envelope surfaces
  - All joints, penetrations must be detailed on design documents
- Cool Roofs are required for Climate Zones 1 to 3
  - Improved solar reflectance
  - Increased insulation requirements
- Glazing limitations
  - Window-Wall Ratio ≤ 40% of gross wall area
  - Major changes to SHGC requirements over 90.1-2007

BECx Process - Design Phase

Similar to Systems Commissioning, BECx is the third-party process of reviewing the design and construction of envelope

Design Phase Steps:

- Creation/Review of Owner's Project Requirements (OPR) and designer's Basis of Design (BOD)
- Commissioning Kick-Off Meeting
- Commissioning Plan
- Design Document Reviews
- Commissioning Specifications including Envelope/ Mock-Up Testing Specifications
- Development of Installation Checklists



BECx Design Reviews

Focus of design review for envelope (waterproofing, dampproofing, vapor barrier, air barrier, insulation, roofing, sealants, glazing):

- Continuity of waterproofing, thermal insulation, and air barriers
  - Attention focused on completeness of details
  - Interaction of differing materials for assemblies
- Potential points of failure
- Constructability
- Maintainability
- Energy performance and sustainability

BECx - Post Construction

The Post-Construction Phase of the Envelope Commissioning process includes:

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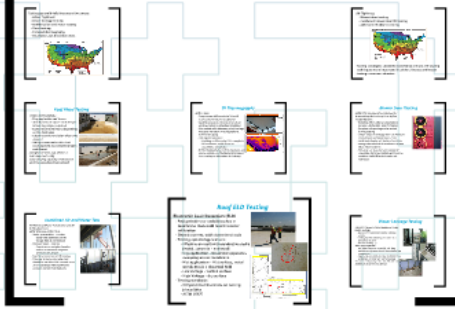
BECx - Construction Phase

The Construction Phase of the BECx process includes:

- Submittal and Shop Drawing Reviews
- Commissioning Meetings
- Pre-Installation Meetings with the various envelope subcontracting trades to set clear expectations and responsibilities.
- Site Observations
- Mock-Up Construction/Testing
- Envelope Testing
  - Water Nozzle Testing
  - Combined Air/Water Testing
  - Hood Testing
  - Infrared Thermography
  - Combined IR and Blower Door Testing

Envelope Testing



BECx Benefits and Costs

Case Studies

What is Commissioning?

Commissioning is an offspring of the nautical tradition of commissioning all of the systems on a sea-going vessel to make sure they are functional before it sets sail

Commissioning is a systematic process, led by a Commissioning Agent (CxA), of ensuring that all building systems perform interactively according to the design intent and the Owner's operational needs

BECx - Owner's Perspective