Building Envelope for the Everyday CxA

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Engineering Principal - Cannon Design
AIA Quality Assurance

Learning Objectives

1. Understanding of Building Envelope Cx and how to integrate into the cx process
2. Understand the roles and responsibilities of BE Cx
3. Knowledge of the Common Pitfalls of BE Cx
4. Case Studies/Lessons Learned from actual projects
INTRODUCTION

Items Covered in this presentation:
• Overview of the Commissioning Process
• Why Building Envelope Commissioning
• Integrating Building Envelope Cx into Project
• The Owner’s Perspective
• The CxA’s Perspective
• Common Pitfalls
• Testing
• Lessons Learned
THE COMMISSIONING PROCESS

Planning
- Commissioning Scoping Meeting
- Define roles and responsibilities
- Review Owners' project requirements
- Schematic Design Review

Design
- Draft Commissioning Plan
- Review basis of Design
- Back Check Design Review
- 95% Construction Documents Review
- 50% Construction Documents Review

Construction
- Commissioning Specifications
- Construction Observation
- Commissioning Coordination Meetings
- Write Pre-Functional Checklists
- Witness Startup
- Write Functional Performance Tests

Acceptance
- Submittal Review
- Finalize Commissioning Plan
- Issues Log
- Resolve Issues
- Testing/Balance Verification
- System Verification

Occupancy
- Review O & M Manuals
- Owner Training
- Short-term Monitoring
- Seasonal Testing
- End of Warranty Review
- Finalize Issue Resolution
- Final Commissioning Report
- Draft Commissioning Report
THE COMMISSIONING PROCESS

**Organization and Preparation**
- Commissioning Specs *(Expanded for Building Envelope)*
- Design Reviews *(Expanded for Building Envelope)*
- Scrub Specs

**Installation Inspections**
- Review Submittals, RFI’s, Change Orders, etc.
- Equipment Start-Up *(Expanded for Building Envelope)*

**Performance Verification**
- Performance Testing *(Expanded for Building Envelope)*
- Building Simulation
- Correction of Deficiencies
- Re-Test of Systems
THE COMMISSIONING PROCESS

• Construction Manager / General Contractor
  o Process management
  o Direct the participation of sub-contractors
  o Site Inspection

• Sub-Contractors
  o Demonstrate correct system installation during functional testing
  o Mock up testing

• Manufacturers and Vendors
  o Provide documentation
BUILDING ENVELOPE COMMISSIONING

WHAT IS CONSIDERED BUILDING ENVELOPE?

- Roof
- Walls
- Windows (Casement, Storefront)

WHY?

The interior and the building enclosure are interdependent. Envelope Commissioning is different than Forensic investigation. Which is conducted when a problem is identified usually after occupancy.
What are the Issues?

• **Roofs**
  - Uplift due to high winds, water leakage

• **Walls**
  - Damage due to improper water drainage and water proofing

• **Doors**
  - Water leakage
  - Ability to open per ADA guidelines

• **Windows**
  - Air and/or Water leakage
# Exterior Enclosure Performance Objectives

- **To Control:**
  - Heat Flow
  - Air Flow
  - Noise
  - Fire
  - Light
  - Infrared
  - Ultraviolet

- **To Eliminate:**
  - Rain Penetration
  - Moisture Build-up

- **Structural Performance**
  - Durability
  - Security
  - Reliability
  - Aesthetics
  - Value
  - Constructability
  - Maintainability
  - Sustainability
ASHRAE CLIMATE ZONES

All of Alaska in Zone 7 except for the following Boroughs in Zone 8:
- Bethel
- Dillingham
- Fairbanks N. Star
- Nome
- North Slope

Northwest Arctic
Southeast Fairbanks
Wade Hampton
Yukon–Koyukuk

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands.
BUILDING ENVELOPE COMMISSIONING

PREDESIGN

**Owners Project Requirements: (Review Only)**

- Owner’s Vision & Directives
- Project Budget & Schedule
- Occupant Requirements
- System Performance & Integration
- Restrictions & Limitations
- Training & Warranty Requirements
- Quality of System, Materials & Construction
- Operations & Maintenance
- Benchmarking & Project Documentation
- Building Envelope Testing requirements (ASTM E 1105-00) (ASTM E 907-96)
### SD and DD

<table>
<thead>
<tr>
<th><strong>Prepare B.O.D. Document:</strong> (Completed By Subconsultant)</th>
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<tbody>
<tr>
<td>- Description of each system option considered:</td>
</tr>
<tr>
<td>- Exterior Enclosure</td>
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<tr>
<td>- Sub-systems</td>
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<td>- Materials and Components</td>
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<td>- Interaction of Building Exterior Enclosure with:</td>
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<td>- Heating</td>
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<td>- Cooling</td>
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<td>- Mechanical and Natural Ventilation</td>
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<tr>
<td>- Lighting</td>
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<tr>
<td>- Building Interior</td>
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<tr>
<td>- Reasoning for Final Building Exterior System</td>
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<td>- Inter-relationships</td>
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<td>- Stiffness/deflection of support structure</td>
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<td>- Daylighting vs. Artificial Lighting</td>
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<td>- Impact on Mechanical Systems</td>
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<td>- Operational Assumptions</td>
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<tr>
<td>- Calculations</td>
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<thead>
<tr>
<th><strong>Determine Systems Manual Structure:</strong> (By Subconsultant)</th>
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<tbody>
<tr>
<td>- A systems manual is developed for each major building exterior enclosure system</td>
</tr>
<tr>
<td>- Roof</td>
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<tr>
<td>- Skylights</td>
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<td>- Atria</td>
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<tr>
<td>- Exterior Walls</td>
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<tr>
<td>- Windows</td>
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<tr>
<td>- Doors</td>
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<tr>
<td>- Sealants &amp; Expansion Joints</td>
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<td>- Control Joints</td>
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<tr>
<td>- Flashings</td>
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<tr>
<td>- Shading Devices</td>
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<tr>
<td>- Curtain Walls</td>
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<tr>
<td>- Plaza Decks</td>
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<tr>
<td>- Planters</td>
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<tr>
<td>- Below-Grade</td>
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<tr>
<td>- Balconies</td>
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<tr>
<td>- Floors</td>
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<tr>
<td>- Others</td>
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</tbody>
</table>
Cx Process Requirements for Const. Doc. Phase

- Systems to be Documented and Tested

- Schedule of Building Exterior Enclosure for:
  - Witnessing Testing Activities
  - Systems and Equip. Accessibility for maintenance and Cx
  - Completion of Construction Checklist
  - Activities relative to substantial completion/project closeout

- Include in Building Exterior Enclosure Spec:
  - Specific Component performance documentation requirements
  - Use of construction checklists
  - Cx Process Activities
QA/QC Plan & Site Specific Testing Plan: (By Subconsultant)
- Verify QA/QC Requirements:
  - Field Testing
  - Manufacturing Performance Testing
  - Submittal & Shop Drawings
  - Laboratory testing for Custom Systems
  - Sample Construction
  - Formal Mock-up Testing Submittal
  - Inspection
  - Pre Construction/installation meeting
- Participants Required for Testing
- Cx Team will develop a range of test verification procedures both QA/QC
  - Components
  - System/Assembly
  - Intersystem
  - Owners Project Requirements
- Random Sampling

Pre-Construction Cx Process Meeting:
- Special Issues relative to sequencing and early installation of equipment should be discussed
- Pre-Construction Conference (Pre-Bid Conference)

Observe & Witness Testing: (By Subconsultant)
- AHSRAE Guideline 0-2005 listed items
- The Cx Authority is to verify that tests were performed
- The Cx is to re-verify test standards and performance criteria to be consistent and appropriate for the building enclosure being tested.
- Verify test Pass/Fail
**Training For Building Envelope: (By Subconsultant)**

- **Seasonal Weather Cycles:**
  - Responsibilities of each O&M position
  - Certification of training comprehension
  - A method of updating operating personnel to changes
  - Repair/modifications/decommissioning

- **Post-Occupancy Performance Verification:**
  - O&M document directory
  - Emergency Operating Procedures
  - Operating Manual meeting O.P.R.
  - Annotation of changes in operation
  - Maintenance Manual, Warranty info. & verified equipment performance data
  - Changes in Maintenance Procedures, Performance verification log forms & modification and repair docs.
  - Equipment test reports
  - Non-Conformance logs
  - As-built, guides and schedules

- **Training during Occupancy & Operations Phase:**
  - Roles & Responsibilities
  - Means of determining level of comprehension
  - Methods of cross-training & tracking
  - Short Narrative of essential exterior enclosure design characteristics.
ROLES AND RESPONSIBILITIES:

- Commissioning Agent
  - Write testing plans
  - Direct and document testing

- Architect, Engineer Design Team
  - Incorporate requirements into specs
  - May attend testing

- Owner Project Managers
  - Witness functional testing
  - Final approval of Cx work products
###Roles and Responsibilities of Team

<table>
<thead>
<tr>
<th>Owner</th>
<th>CXA</th>
<th>Design Team</th>
<th>Bldg Env Sub</th>
<th>Contractors</th>
<th>Specialists</th>
<th>Bldg Ops</th>
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<td>Commissioning Authority</td>
<td>Project Manager</td>
<td>Architect</td>
<td>Structural Engineer</td>
<td>Mechanical Engineer</td>
<td>Electrical Design Engineer</td>
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<td>Lighting Design Professional</td>
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<td>Electrical Design Engineer</td>
<td>Lighting Design Professional</td>
<td>Systems Design Engineer</td>
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**Key**
- **P** - Provide
- **A** - Approve
- **R** - Review
- **U** - Use
- **I** - Input From

###Notes
- **5.2.2 Owner's Project Requirements**
- **5.2.4 Commissioning Plan**
- **5.2.4.4 Issues Log & Report**
- **5.3.1 Acceptance & Commissioning Process Record**

###Design
- **6.1.1 Owner's Project Requirements (OPR) Update - All Phases**
- **6.2.2 Basis of Design - All Phases**
- **6.2.3 Commissioning Plan - Update**
- **6.2.4 Construction Specifications for Commissioning**
- **6.2.5 Construction Checklists**
- **6.2.6 Systems Manual Outline**
- **6.2.7 Commissioning - Focused Design Reviews**
- **6.2.8 Issues Log & Report**
- **6.5.1 Acceptance & Commissioning Process Record**

###Construction
- **7.2.2 Pre-Bid Conference Commissioning Briefing**
- **7.2.4 Owner's Project Requirements**
- **7.2.5 Commissioning Plan & Inspection Pre-Bid Update**
- **7.2.6 Pre-Construction Commissioning Process Briefing**
- **7.2.7 Submittal Review Comments**
- **7.2.8 Commissioning Milestone Schedule**
- **7.2.9 Test Procedures**
- **7.2.10 Test Procedures - Components**
- **7.2.11 Test Procedures - Systems**
<table>
<thead>
<tr>
<th>OWNER’S PERSPECTIVE</th>
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<tbody>
<tr>
<td>• A professional team including architect/engineer/qualified contractors have been engaged</td>
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<tr>
<td>• Any VE conducted does not impact quality</td>
</tr>
<tr>
<td>• Contractors, Project and Construction Managers are conducting all <strong>needed tests</strong> to ensure Quality</td>
</tr>
<tr>
<td>• Building envelope should have <strong>NO</strong> problems</td>
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<tr>
<td>• QA/QC process via Controller</td>
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</table>

*The reality may well be different.*
QUESTION & ANSWER: PART I
<table>
<thead>
<tr>
<th><strong>COMMISSIONING PROVIDER’S PERSPECTIVE</strong></th>
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<tbody>
<tr>
<td>• Must Detail Building Envelope Requirements in Specification</td>
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<tr>
<td>• Integrating Building Envelope into Cx Specifications</td>
</tr>
<tr>
<td>• Clearly Define the Roles of all Participants</td>
</tr>
<tr>
<td>• Define the required Building Envelope Testing</td>
</tr>
<tr>
<td>• Destructive Testing? Factory Testing?</td>
</tr>
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</table>

**Must make clear to Owner that CxA is acting in their best interest.**
COMMISSIONING PROVIDER’S PERSPECTIVE

- Clarify role of “Third Party” Independent Testing firm
- Coordinate with Architect on Design Review requirements
- Building Enclosure Consultant role vs Building Envelope Cx firm
- Roles if project is delivered as Design/Build or Design Assist
If the Envelope testing is bypassed…

- Envelope may have issues
- Water leaks
- Snow/ice formation on windows
- Excessive infiltration
- Visual damage

Condensation observed on interior window frames

Ice formation observed on exterior near panel seams and weep holes
COMMON PITFALLS

- Building envelope moisture entry [Aldous 2008]
- Damage to brick façade of pool building due to lack of proper sealing and air management
- Photosensor “sees” the electric lamps rather than task-plane illumination
- Photosensor (for daylight harvesting) shaded by duct
- Air leakage in an underfloor air-distribution system
- Failed window film applications
COMMON PITFALLS

• Foam thickness not per specification on Mock Up causing a rejected system.

• High moisture content of wood did not allow adhesive to bond correctly – barrier developed air pockets

• Damage to waterproofing membrane at footing

• AVB Membrane seams are opening up at the soffit
COMMON PITFALLS

- Who is developing the Enclosure Testing?
- Who will “approve” the submittals?
- Who will determine what is acceptable testing?
- Key peer review vs Cx review?
- Leader of Mock up testing?
- Review of day to day BE craftsmanship?
 TESTING

• Field Testing
• Infra red testing of roof and windows
  o This is a “workhorse” of envelope Commissioning
  o Can be used for roof and windows
  o No destructive work is required for testing
  o Better done in winter or colder months

• Window water leakage testing using field rigs
• Document problems
• Note issues to be resolved
FIG. 1 General Arrangement of Water Penetration Test Apparatus
INFRARED TESTING

Roof

Thermal Bridging

Cooler ------------------------------------------------------------- Warmer
The building may be experiencing “stack effect”. The warm thermal patterns in the thermogram may be caused by small amounts of warm air exfiltration.
Note heat losses around the window frames. These metal frames often conduct a substantial amount of heat because metal is an excellent conductor of heat and cold, and the frames typically do not have as much R-value as high efficiency glazing, or insulated wall sections.
**ENVELOPE TESTING**

**IN SUMMARY:**

- Envelope testing a key commissioning element
- Required to verify:
  - Construction quality
  - Design intent is met
- Teamwork is critical
  - All parties must play their role
  - Follow contractual lines
  - Must be adequately specified
- Hidden issues are understood earlier
REFERENCES AND DOCUMENTATION ROOFS:

- **Factory Mutual (FM) Loss prevention Data Sheet 1-52 (FM 1-52)**
  Provides two methods of uplift testing
  - Negative Pressure Test
  - Bonded uplift test
- **ASTM E 907** (Standard test Method for Field Testing Uplift Resistance of Adhered Membrane Roofing Systems)
- Concerns in industry regarding accuracy and applicability of these tests
ENVELOPE TESTING

REFERENCES AND DOCUMENTATION:

• **AAMA 502-08** (Voluntary Specification for Field Testing of Newly installed Fenestration Products)
• **AAMA 503-08 502-08** (Voluntary Specification for Field Testing of Newly installed Storefronts, Curtain Walls and Sloped Glazing Systems)
• **AAMA 511-08** (Forensic Investigations)
• **ASTM E 2128** (Standard Guide for Evaluating Water Leakage of Building Walls)
• **ASTM E 783** (Standard Test Method for Field Measurement of Air Leakage through installed Exterior windows and Doors)
• **ASTM E 1105** (Standard Test Method for Field Determination of Water Penetration of installed Exterior Windows, Skylights, Doors and Curtain Walls and Doors by Uniform or Static Air Pressure Difference Measurement of Air Leakage through installed Exterior windows and Doors by Uniform or Cyclic Static Air Pressure Difference)
CASE STUDY: Albert Sherman Center

- 485,000SF New R+D Facility
- Seeking LEED Silver
- 300,000 SF of space for a wet research laboratory, clean rooms, core research space, administrative space and vivarium
CASE STUDY: Smithsonian Institution

- National Museum for African American History and Culture
- 15-acre site
- Last museum to be placed on the National Mall
- $500 Million Project
- Seeking LEED Gold
Massachusetts School Building Authority (MSBA) is the principal state agencies which supports public school projects in Massachusetts.

**REPRESENTATIVE PROJECTS:**
- Avery Elementary School
- Freeman Elementary
- Maynard Middle School
- Wayland High School
- Hudson Middle School
- Willard Elementary School
CASE STUDY: MSBA

DESCRIPTION

Among other initiatives it has adopted envelope commissioning as an important step towards Quality assurance in their Green Repair program.

Approximately 85 projects have been undertaken with Commissioning contracts totaling over $8 million.

MSBA requested qualifications from qualified firms to generate a pool of Envelope Commissioning firms. These firms are given school window and roof replacements projects for Commissioning.
CASE STUDY: MSBA

OBSERVATIONS

This provides a systematic process of quality assurance to public schools envelopes.

Before the program was initiated local school districts were less inclined to perform envelope commissioning.

CxA was engaged in different stages of the project. In some cases only final field inspection was possible. In other full design review was possible.

Envelope Cxing is still not well understood and roles and responsibilities not yet firmed.

Several contractors are still not full team players.
<table>
<thead>
<tr>
<th>Items to Improve</th>
<th>Best Items to Repeat</th>
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<tbody>
<tr>
<td>Improved Coordination with Architect</td>
<td>Availability to the Owner</td>
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<tr>
<td>Regularly Scheduled Cx Progress Meetings with Owner</td>
<td>Flexibility of Cx Provider Scheduling and Testing</td>
</tr>
<tr>
<td>Define testing early on in Schematic Design</td>
<td>Early Identification (Schematic Design) of Issues and Continued Tracking of Open Item</td>
</tr>
<tr>
<td>Utilize the OPR to better define BE testing requirements and Roles</td>
<td>Constant Communication with team using tools such as the Cx Matrix to track schedule</td>
</tr>
<tr>
<td>Design Review meetings to be mandatory</td>
<td>Determine M+V roles during the design phase (Envelope)</td>
</tr>
<tr>
<td>Additional controls integration meetings needed</td>
<td>LEED NC requirements for Building Envelope</td>
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QUESTION & ANSWER: PART II
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