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Building Enclosure Commissioning

PCI designer'snotebook

BUILDING ENCLOSURE COMMISSIONING

Building Enclosure Commissioning (BECx) is a holistic process developed with input from stakeholders in the real estate development, design, construction, and property management communities to supplement and strengthen the project delivery process and deliver higher performing buildings and structures. BECx was originally conceived as part of a more broadly based whole-building Commissioning (Cx) program that began largely as a test-and-balance activity in the HVAC industry but today has evolved to include a wide range of processes intended to ensure fully integrated and ***quantifiable*** building performance across all practice areas, disciplines, industries, and trades.

Why Commission the Building Enclosure?[1]

In any effort to produce a new building project or manage an existing building asset, proper design and maintenance of the building enclosure is vital. This is even more critical when trying to create or manage a sustainable building. In general, the transfer of heat and moisture between the building interior and exterior has a fundamental impact on the design and eventual operation of a building asset. The heat transfer through the building envelope, including both the facades and the roof, dominates the design requirements in virtually all buildings with floor plates smaller than 15,000 square feet and, depending on the building configuration, can have a significant effect for buildings with larger floor plates. Generally speaking, the impact of the building envelope penetrates to 15 feet from the envelope in most buildings. Therefore, proper design and maintenance of the building envelope is crucial to the sustainability and eventual durability of the asset. Building envelope failures quickly obviate the best laid plans for an energy-efficient building.

Energy efficiency is not the only goal of a sustainable building. Other goals include indoor environmental quality and durability. Simply put: uncontrolled rainwater penetration, condensation potential, and moisture ingress are three of the most common threats to the long-term durability, structural integrity and performance of the building enclosure. In the past, statistical data has suggested that collectively they represent up to 80 percent of all construction-related claims in the United States.[2] Today, a new pipeline of litigation has been added to that list— one that arises not simply from the deleterious effects of moisture intrusion, but rather from the noble, though perhaps short-sighted and frequently ill-informed objectives established for energy efficiency in the name of sustainable design. The continuation of this trend is troubling, and has only taken on added significance when one considers the changing role and perception of the architect in the project delivery process.

1. "Trust but Verify: Building Enclosure Commissioning in Sustainable Design," Real Estate Issues, "Special Focus Issue: Understanding the Business of Green," Vol. 33, Number 3, 2008, Chicago

2 Bomberg, M.T. and Brown, W.C. (1993), "Building Envelope and Environmental Control: Part 1-Heat, Air and Moisture Interactions," Construction Canada 35(1), 15-18.

In an effort to more clearly deal with the risks associated with the failure of design and maintenance of the building enclosure, a whole new area of technical design, forensic analysis and redesign has arisen. The primary motivation for the recent concept and practice of Building Enclosure Commissioning (BECx) has been to address the common technical deficit of most architectural detailing practices and the increased recognition of owners and insurers of the significant losses in functionality and asset damage as a result of poor building envelope design and maintenance.

Changing Role of the Architect

Professor Barry Yatt of the School of Architecture at Catholic University in Washington, D.C., recently wrote[3]: "Architects see themselves and, to a larger extent, are seen by society as "creative types." As a culture, we recognize these individuals as renaissance people—licensed professionals who think in the abstract and possess the rare combination of vision, creativity and the scientific rationale necessary to bring us informed, responsive and, in some instances, truly inspiring and thought-provoking design. This notion of the architect's place in our society is reaffirmed time and again in the popular press when business leaders and politicians are referred to as the architects of a given mission or success—be it the start of a successful new business or, perhaps, the outcome of a successful piece of legislation. We use the term reverentially because, as a society, we have come to recognize architects as individuals with a proven ability to solve major problems through the use of a creative, yet structured and thoughtfully applied intellectual process." Ironically, this societal view of the architect has begun to apply less and less to those who, by definition, are actually engaged in the practice of architecture. Due largely to development models that increasingly reflect near-term profitability rather than long-term durability and performance—and the corresponding increase in liability and risk associated with this shift—architecture has evolved into a profession that, in many respects, is better known for the services and expertise it no longer provides than for the services that were once the foundation of the profession. In-depth technical research, comprehensive and effective detailing during the design phases of a project, and a commitment to regular inspections of the work during construction to ensure proper installation and performance have increasingly fallen victim to the demands of compressed schedules and often, an unrealistically low budget. Architects recognized this shifting demand and responded by reducing their scope of services—and attempting to shield themselves from liability—by outsourcing these tasks to what has become a breathtakingly large and still expanding field of design consultants. Developers, for their part, unwittingly contributed to this shift by creating a more competitive environment for design services during the conceptual stages of a project—an environment that, while perhaps more cost-effective in the near term, nonetheless contributed to the compartmentalization of design and an attempt, in many instances, to redistribute design responsibility "downstream" into the construction industry and trades—arguably lowering the bar for a profession that is increasingly unwilling or unable to invest the time and resources necessary to respond to the rapidly evolving technical challenges of a project.

"It should come as no surprise, then," says Professor Yatt, "that developers increasingly turned to consultants

3 From an unpublished article: "Toward a Meaningful Architecture: Educating a New Profession of 'Stewards,'" Yatt, Barry D., Professor of Architecture, Catholic University of America, Washington, D.C.

to fill this void. And architects who did, in fact, invest the time and financial resources to design responsively, increasingly found themselves facing a market that no longer expected to see them in this role." While design responsibility (and fees) for architects engaged in traditional practice have suffered, the number of players and costs associated with a project team have continued to increase, with (arguably) little or no significant reduction in risk for the owner/developer, and only minimal gain in the long-term durability and performance of the buildings that continue to emerge from this process.

How do we address this concern? One popular refrain among owners, developers and contractors is to reflect wistfully upon the idea of the architect as master builder " that legendary paragon of creativity and pragmatism that once guided both design and construction before the increasing complexity of building technology warranted building codes and public regulation of the architecture profession." As tempting as it may be for architects to want to resurrect that ideal, the notion that the profession will recapture that mantle is one that can only be viewed through the romantic lens of history. It holds little or no promise when viewed through the multi-faceted prism that has come to define project delivery today. Perhaps, then, it is more appropriate to consider the possibility of an individual, or team of professionals, who serve as consultants to, and stewards of, the project delivery process on behalf of the Owner. Truly independent, third-party professionals who possesses a level of base-building knowledge and technical competence necessary to understand, evaluate and effectively balance the desire to take advantage of rapidly advancing construction materials and technologies with the reality (and often competing interest) of managing initial project cost, life-cycle cost, short- and long-term environmental impact, energy efficiency, and the long-term durability, serviceability and performance of the modern building enclosure. Candidly, these are principles once considered fundamental to good design and construction practice. Today, they are the principles that form the basis of Building Enclosure Commissioning (BECx) and the goal of delivering, rather than simply promising, higher performing buildings and structures.

The Building Enclosure Commissioning Process[4]

- Optimum building performance begins at conception. In order to achieve a fully integrated, high-performance building—one in which the design of the building enclosure reaches beyond the aesthetic and begins to support and enhance the comfort and productivity of the end user—it is critical that issues of service-ability, durability and performance receive the same weight as those associated with programming, massing, site orientation, and climate. These concepts are inextricably linked, of course, and must be fully considered during the early stages of a project. The traditional Commissioning (Cx) process has long held that optimum building performance can only be delivered through thoughtfully prepared, fully integrated, and technically sound design that is quantifiably tested during construction and then (ideally, though not always) validated after occupancy by the cost-effective, energy-efficient operation and maintenance of a building throughout its anticipated use and service-life. The BECx process is a direct reflection of that approach and was developed in response to a still-growing demand in the marketplace for higher

4 From an unpublished article: "Toward a Meaningful Architecture: Educating a New Profession of Stewards,"
Yatt, Barry D., Professor of Architecture, Catholic University of America, Washington, D.C.

- performing buildings and an increasing awareness among owners and developers regarding the changing role of the architect in the project delivery process, increasing compartmentalization of the design profession itself, and (arguably) the declining skill levels that we continue to see in certain construction trades.

Setting the Standard

Published guidelines and standards for BECx and Cx that were developed as a result of an open, consensus-based standards-development process and are now eligible for adoption, in whole or in part, by federal, state, and local building code governing bodies and jurisdictions include:

- ASHRAE Guideline 0, *The Commissioning Process*
- ASTM E2813, *Standard Practice for Building Enclosure Commissioning*
- ASHRAE Standard 202, *Commissioning Process for Buildings and Systems*

ASTM E2813 includes, by reference, ASHRAE Guideline 0 and the National Institute of Building Sciences (NIBS) Guideline 3 (2006), ***E**xterior Enclosure Technical Requirements for the Commissioning Process*, the latter of which was recently updated (2012) but is scheduled to be withdrawn by NIBS and replaced in 2014 by a new ASTM *Standard Guide for Building Enclosure Commissioning* under a joint-development agreement between ASTM and NIBS. As the first consensus document ever published on BECx, ASTM E2813 is significant in that it establishes for the first time:

- Minimum enforceable baseline ("Fundamental") and benchmark ("Enhanced") levels of BECx;
- Clearly defined distinctions between the role of the BECx service-provider and Architect/Engineer-of-Record:
  - √ *"The BECx 'Agent' or 'Authority' (BECxA) refers specifically to the individual or firm retained by the Owner to develop, manage, and be in responsible charge of the BECx process, including individual members and technical specialists that may comprise the BECx team";*
  - √ *"The role and responsibilities of the BECxA… are not intended to supersede or otherwise replace the contractual obligations reserved specifically for the parties responsible for the design and construction of a building or structure, nor the duties… assigned to those parties by applicable regulatory or statutory law."*
- A requirement for independent, third-party design review of the construction document drawings and specifications at milestone intervals during the Design Phase of a project;
- A "roadmap" (Annex A.1) to help guide the development of appropriately prioritized, comprehensive, and enforceable Owner Project Requirements (OPR) at the outset of a project that address the following fundamental performance attributes:
  - √ Energy
  - √ Environment
  - √ Safety
  - √ Security

- √ Durability
- √ Sustainability
- √ Operation and Maintenance

- A table (Annex A.2) of internationally recognized, consensus-based test standards and methodologies available to owners, developers, and design professionals to determine - *quantifiably* and at milestone intervals during construction - if the *installed performance* of a building and its enclosure satisfies the requirements of the OPR as reflected in the contract document drawings and specifications, and;
- A list of minimum required ***Core Competencies*** of the BECx service-provider to ensure that a baseline level of knowledge, skills, and abilities appropriate to the project exists among the individual members of the BECx team and, more critically, the Architect/Engineer-of-Record and individual consultants to the design team.
- The minimum required Core Competencies outlined in ASTM E2813 are particularly noteworthy in that they will, over the coming year, serve as the basis for the development of a new fully accredited ***ASTM/NIBS BECx Personnel Certification and Training Program*** that will be available to interns and practicing professionals for career advancement in the design and construction industry. Over time, those same core competencies will be further developed and refined to align with curricula currently being taught at colleges and universities in North America in building science, materials science, and the "physics" of climate-specific building enclosure behavior and performance - the goal being to use this effort as a catalyst toward the development of more uniform, widely available, and effective education and training for the *next* generation of architects and engineers in these and related technical disciplines.

Raising the Bar

As currently published, ASTM E2813 requires the BECxA to assemble a team that can demonstrate a minimum level of proficiency in the following Core Competencies:

- o **Building and Materials Science**
  - √ Principles associated with heat transfer via conduction, convection, radiation, and air infiltration/exfiltration;
  - √ Principles associated with moisture storage and transport via gravity, diffusion, convection, capillary action, absorbed flow, and osmosis; and
  - √ Characteristics and behavior of enclosure-related materials, components, systems, and assemblies when specified for a given application, geographic region, location, exposure, or climate, and corresponding influence on workability, durability, serviceability, performance, and anticipated service-life.

- **Procurement and Project Delivery**
  - √ Influence of the project delivery method selected by the Owner on the scope, adaptation, implementation, and cost of the BECx process as defined in this practice;
  - √ Influence of the number and type of contracts established between the Owner and the design and construction teams on the role and responsibilities of the BECxA and individual members of the BECx team;
  - √ Influence of design and construction scheduling, phasing, and sequencing of the work on the scope, adaptation, implementation, and cost of the BECx process as defined in this practice;
  - √ Influence of the experience, qualifications, technical depth, and commitment of the design and construction teams to the BECx process on the role and responsibilities of the BECxA, the range and technical depth required of the BECx team, and the anticipated scope and cost of the BECx process.
- **Contract Documents and Construction Administration**
  - √ Interrelationship and commonly understood hierarchy that exists between Procurement Documents, Contract Documents, Contract Drawings and Specifications developed during the Design Phase of the BECx process, as well as submittals and legally binding Instruments of Change issued during the Pre-Construction (Procurement) and Construction Phases of the BECx process, including but not limited to: Addenda; Submittals; Architect's Supplemental Instructions and Field Directives; Construction Change Directives, and; Change Orders;
  - √ Influence of enclosure-related design, detailing, and integration on total building performance, including at a minimum consideration of the performance attributes listed in this practice;
  - √ Influence of product selection, allowable construction tolerances, and dimensional requirements to accommodate environmental and service loads on detailing at interface conditions between enclosure-related materials, components, systems, and assemblies, and; the corresponding influence on sequencing, phasing, and coordination of trades during the Construction Phase of the BECx process;
  - √ Importance of material compatibility and continuity of primary heat, air, and moisture control layers throughout the building enclosure on total building performance and the appropriate mitigation of risks associated with improperly managed heat, air, and moisture transport across the building enclosure;
  - √ Importance of the timely preparation and distribution of subject-direct, technically sound, and actionable documentation and feedback to the Owner, design, and construction teams throughout the Construction Phase of the BECx process.

- **Performance Test Standards and Methodology**

  - √ Pre-construction laboratory and field-applied test standards and methodology referenced in this practice and their intended use and application in evaluating the durability, performance, constructability, and anticipated service-life of enclosure-related materials, components, systems, and assemblies;
  - √ Importance of establishing appropriate and quantifiable thresholds of performance and clear and unambiguous definitions of failure for enclosure-related materials, components, systems, and assemblies to validate the OPR and BOD, and to allow for proper enforcement of the contract documents;
  - √ Influence of modifications to the intended use and application of pre-construction laboratory and field test standards and methodology on the appropriate interpretation of test results and their relevance to the requirements of the contract documents;
  - √ Importance of ensuring the timely, clear, and unambiguous translation of all modifications to the design, construction, and integration of enclosure-related materials, components, systems, and assemblies arising from pre-construction laboratory testing to the field during the Construction Phase of the BECx process;
  - √ Importance of recognizing the distinction between errors and omissions in architectural or product design, or both, versus defective installation or workmanship, or both, when interpreting field test results, and; the techniques available during the development and implementation of field testing protocols that will minimize the risk for confusion and misinterpretation relative to the requirements of the contract documents;
  - √ Distinction between test standards and methodologies "recognized in the industry" or otherwise developed by industry or trade associations versus test standards developed by independent standards-writing organizations and the impact, if any, on the enforcement of the contract documents when both are included in the project specifications.

Defining the Process

The process itself aligns closely with the process outlined in ASHRAE Guideline 0 and includes the following phases, sub-phases, and tasks:

- **Pre-Design**

  This is the preparatory phase of a project when information gathered by the CxA/BECxA regarding the overall programmatic requirements for a building or structure and the goals and objectives of the owner/developer are defined and included in the Owner's Project Requirements (OPR). The OPR is a written document that establishes the owner/developer's goals and objectives with regard to building type and intended use, project delivery method, budget and schedule, and expectations associated with each of the performance attributes outlined below[5]. The OPR serves as the foundation for the selection of a design team (if an Architect/Engineer-of-Record has not already been engaged), development of a Cx/BECx Plan, and the start of the Design Phase of the project.

- **OPR Performance Attributes**
  - √ Energy
  - √ Environment
  - √ Safety
  - √ Security
  - √ Durability
  - √ Sustainability
  - √ Operation and Maintenance
- **Key Components of a Cx/BECx Plan**
  - √ Overview of the Cx/BECx Process
  - √ Roles and Responsibilities of the Cx/BECx Team Members
  - √ Cx/BECx Communication Protocols with the Project Team
  - √ Cx/BECx Schedule of Activities
    - Milestone Cx/BECx Meetings with the Project Team
    - OPR Update/Refinement During the Design Phase
    - Outline of Cx/BECx activities During the Pre-Construction, Construction, and Occupancy and Operations Phases
  - √ Forms and Templates to be used for Communication with the Project Team
  - √ Procedures and checklists to be used for Project Team Performance Verification Relative to the OPR

Of particular value during this phase is the development of a written OPR and initial Cx/BECx Plan by the owner/developer and (if engaged) Architect/Engineer-of-Record for the project. The OPR and Cx/BECx Plan are typically developed and submitted by the CxA/BECxA for initial review and approval, then further updated and refined during the Design Phase of the project for final review and approval by the owner/developer prior to contract award and the start of construction.

• Design

This is the phase during which the OPR is translated by the design team into construction document drawings and specifications. As part of this phase, a Basis-of-Design (BOD) document is established that clearly conveys the solution developed by the design team and how it is responsive to the OPR. The BOD is typically prepared in narrative form and is further supported by two- and three-dimensional drawings and models illustrating

5 See ASTM E2813, Annex A1, OPR Development Guideline, for additional information and guidance

site orientation, context, massing, intended ratio of glass to opaque wall and roof area, programmatic floor plans, and supplemental information regarding the potential influence of building type and intended use, geographic location, and climate on material selection and design. Milestone sub-phases of the design process are outlined below, together with an overview of the tasks typically included in each:

- **Schematic Design**
  - √ Evaluate Enclosure Materials, Components, Systems and Assemblies
    - Aesthetic Objectives
    - Functional Performance Requirements
      - Structural
      - Mechanical
      - Environmental
      - Operation and Maintenance
    - Budget and Schedule Limitations
    - Overall Responsiveness to the OPR
  - √ Establish the Enclosure BOD
  - √ Update the Cx/BECx Plan
  - √ Refine the OPR (if necessary)
- **Design Development**
  - √ Select and Provide Detailing for Enclosure Materials, Components, Systems and Assemblies That are:
    - Technically Sound
    - Safe
    - Serviceable
    - Durable
    - Cost Effective
    - Environmentally Conscious
    - Responsive to:
      - Location
      - Exposure
      - Climate
      - Building Use/Occupancy
      - AnticipatedService Life

√ Design for Effective Management of Heat, Air, and Moisture Transport

- Alignment of Environmental Control Layers, including:
  - Air
  - Water
  - Thermal
  - Vapor
- Continuity of Environmental Control Layers
  - Exterior Wall and Roof Penetrations
    - Windows/Doors/Skylights
    - Utilities
    - Structural
  - Exterior Enclosure Interface Conditions, including:
    - Wall-to-Stucture
    - Wall-to-Wall
    - Wall-to-Roof
    - Wall-to-At Grade/Below Grade Waterproofing
    - Wall/Roof-to-Adjacent Construction
- Computer Modeling Testing and Analysis, including:
  - Wind-Tunnel Testing or Computational Fluid Dynamics (CFD) Modeling
  - One-Dimensional Hygrothermal Analysis (WUFI® or similar)
  - Analysis (THERM 5.2® or similar) to Determine Thermal Bridging and Condensation Potential
  - Analysis of Solar Orientation/Exposure and Ratio of Glass-to-Opaque Wall Area
  - Analysis of Snow and Ice Accumulation/Accretion
  - Acoustical Analysis/Testing
  - Lighting/Daylighting Analysis
- Product-Based BODs
  - Selection and Use of Actual Product Profiles and Configurations as a Basis-of-Design to Convey Design Intent at Enclosure Penetrations and Interfaces
    - Facilitates Alignment and Continuity of Environmental Control Layers at Enclosure Interface Conditions
    - Increases the Enforceability of the Contract Documents
    - Minimizes the Risk for Additive Change Orders

- √ Specify to Ensure Fully Integrated Installation and Quantifiable Performance
    - Comprehensive Submittal Requirements
        - o Product Test Data
            - Material Compatibility (Chemical and Adhesive)
            - Limitations Associated with Installation and Exposure
            - Suitability for Intended Use
            - Durability and Performance
        - o Product Design Requirements
            - Pre-Engineered and Pre-Fabricated Systems and Assemblies
        - o Coordinated Shop Drawings
            - Alignment of Environmental Control Layers
            - 2-D and 3-D Interface Detailing Between Trades
            - Consideration of Allowable Fabrication and Installation Tolerances
            - Consideration of Construction Sequencing and Coordination of Trades
    - Performance Testing and Validation
        - o Product Testing to Confirm Material Compatibility, Durability, and Baseline ("Gateway") Performance
        - o Project-Specific Pre-Construction Laboratory and Field Testing
            - Laboratory Analysis and Materials Testing
            - Full-Scale Off-Site Laboratory Mock-Up Testing
            - Full-Scale Field-Constructed Mock-Up Testing
            - Field Testing at Milestone Intervals During Construction
- √ Respond to Initial Independent/Third-Party Design Peer Review
- √ Re-Evaluate Responsiveness to the OPR and BOD
- √ Update the Cx/BECx Plan
- √ Develop a Cx/BECx Specification Section (Division 01)
- √ Refine the OPR (if necessary)

o Construction Documents

- √ Respond to Final Third-Party/Independent Design Review
- √ Develop Final Construction Contract Document Drawings and Specifications
    - Reflects Final Product BODs as appropriate
    - Includes Detailing at Interfaces and Penetrations Necessary to Convey Design

Intent Regarding the Alignment and Continuity of Environmental Control Layers, *Prior to Bidding*

- Is Responsive to the Final OPR
    - Includes Final Cx/BECx Specification Sections
    - General Cx Requirements
    - Project-Specific BECx Requirements
    - Product or System-Specific Performance Testing Requirements
- Includes Requirement for a Contractor Building Enclosure Quality Control Program

√ Document Final/Approved Design Phase OPR (Record Copy)

√ Document Final/Approved Design Phase Cx/BECx Plan (for Coordination with GC/CM Quality Control Plan after Construction Contract Award)

Of particular value during this phase is the establishment of a properly coordinated and comprehensive set of specifications for the Cx and BECx process that include both fully integrated and product/system-specific performance test requirements in the appropriate sections of the technical specifications. General commissioning requirements are typically defined in a stand-alone section of Division 1 in the project specifications (MasterSpec 019113, for example) and apply only to the generic implementation of the Cx process itself, with no direct correlation to the systems or equipment to be tested. BECx requirements are also defined in Division 1 (MasterSpec Section 019119); however, that section typically includes requirements that correlate directly to the performance testing, quality assurance, and quality control requirements included in each of the enclosure-related sections of the project technical specifications. To avoid confusion, potential conflict, added cost, and delay during the Pre-Construction and Construction phases of the project, it is critical that the technical specifications establish quantifiable, clearly defined, and enforceable requirements for performance testing. The definition of "failure" - both in the context of product/system-specific individual component testing and full-scale, fully integrated mock-up testing – must be clearly stated, tightly coordinated, and appropriately applied by the design team throughout each section of the project specifications. Regardless of whether or not BECx is voluntarily implemented or otherwise required on a project, a failure in this area by the design team during the Design Phase of a project is arguably the single most frequent source of conflict and potential litigation during the project delivery process.

- **Pre-Construction**

The Pre-Construction or "Procurement" phase is the stage that, depending upon the project delivery method selected by the owner/developer, will typically include bidding, construction contract negotiation, contract award, and preparatory activities in advance of or concurrent with site work and the start of construction. The role and responsibilities of the CxA/BECxA during this phase include, but may not be limited to, documentation and technical assistance to the owner, design, and construction teams as outlined below:

- Attend Pre-Bid Meeting
- Provide Technical Assistance

- √ In Response to Bidder Requests for Clarification
- √ During Preparation of Addenda to Bidders
- √ Review and Evaluation of Bids

- o Coordinate and Attend Project Kick-Off and Pre-Construction Meetings
- o Coordinate and Chair Cx/BECx Planning Meeting with Construction Team

  - √ Review Roles and Responsibilities of the CxA/BECxA During Construction
  - √ Discuss CxA/BECxA Plan and Specification Requirements with the Construction Team
  - √ Coordinate CxA/BECxA Plan with the Contractor Quality Control Program

- o Provide Technical Assistance During Shop Drawing and Technical Submittal Review

  - √ Review for Compliance with the OPR as Reflected in the Approved Contract Documents for Construction
  - √ Evaluate "Qualifications and Exclusions" and "Value Engineering" Options for Potential Influence on the Functional Performance Requirements of the Project and the OPR as reflected in the Approved Contract Documents for Construction
  - √ Confirm Material Compatibility, Alignment, and Continuity of Environmental Control Layers at Enclosure Penetrations and Interface Conditions Between Subcontractors and Trades
  - √ Confirm Coordination of Allowable Fabrication and Installation Tolerances
  - √ Consider Construction Sequencing and Coordination of Trades ("Constructability")
  - √ Conduct Off-Site "Plant" Visits to Supplier/Subcontractor Manufacturing Facilities
  - √ Observe and Document Fabrication Processes and In-House Quality Control Program
  - √ Interview Production Manager, Quality Control Manager, and Floor Supervisor(s)/ Superintendent(s) in Responsible Charge of Fabrication
  - √ Evaluate Production Capacity, Quality Control Program, and Availability/Depth of Engineering and Technical Support

- o Observe, Document, and Provide Technical Assistance During Pre-Construction Laboratory and Field-Constructed Mock-Up Erection and Testing
- o Provide Technical Assistance and Documentation of Refinements to the Original Contract Document Drawings and Technical Specifications Resulting from the Activities Included in this Phase
- o Update and Refine the Design Phase OPR as necessary
- o Update and Refine the Design Phase Cx/BECx Plan as necessary

Of particular value during this phase is the successful completion of a pre-construction laboratory and/or field-constructed mock-up (or series of mock-ups) that typically include one or perhaps several full-scale assemblies of representative sections of the above-grade building enclosure. While the perception on many projects is that mock-up testing is simply a "pass/fail" moment in the project delivery process, the added-value of this step involves much more than simply the ability pass the series of performance tests specified for the project (typically based on ASTM E2099). Participation by the BECxA with representatives of both the design and construction team *prior to* and during testing often yields valuable insight regarding the influence of construction sequencing and coordination of trades on constructability and performance. This level of participation can also result in further review and refinement of material profiles and configurations ("product design") and interface detailing between primary façade and roof components at a stage in the process when these changes can be addressed with minimal impact on overall project schedule and cost.

Success during this step is typically defined by test results that confirm the ability of the fully assembled mock-up to satisfy the requirements of the contract documents for each of the performance attributes included in the OPR, including structural performance and the effective management of heat/air/moisture transfer and corresponding risk for condensation and/or bulk rainwater penetration that can lead to long-term corrosion and microbial growth - often in the concealed spaces of the building enclosure.

- ## Construction

This is the phase during which systems, and assemblies are installed, inspected, and tested to confirm compliance with the final OPR and BOD as conveyed in the approved contract documents. Responsibilities of the BECx service-provider during this phase include:

- Scheduling and coordination of Cx/BECx Process activities with the project schedule and Contractor Building Enclosure Quality Control Program
- Development and documentation of tests procedures, checklists, and data forms
- Coordination and documentation of periodic Cx/BECx Team meetings
- Observe and document the work-in-progress for compliance with the OPR through periodic site visits
- Witness and document the construction and performance testing of all field-constructed, enclosure-related mock-ups
- Witness and document the field testing of representative enclosure materials, components, systems, and assemblies at milestone intervals during construction
- Identify, diagnose, and track issues and deviations from the OPR and BOD as conveyed in the approved contract documents and resolution of same
- Prepare BECx field reports and related documentation and maintain a Cx/BECx " Issues" or "Tracking" Log that identifies all enclosure-related non-conforming work for review and remedial action by the construction team
- Documentation of any modifications to the OPR and Cx/becx Plan that may be required as a result of circumstances that arose or decisions that were made during construction

The BECx Final Report and Project Close-Out Manual(s) are delivered at or near substantial completion of this phase and include copies of all enclosure-related performance test results, off-site quality control reports for enclosure-related supplier/manufacturers to the project, construction observation reports, photographs, sketches, RFIs, Change Orders, Architect's Change Directives, and similar information documenting the completion of this phase of the BECx process. Also included in this documentation is a summary of all "open" and "closed" enclosure-related issues and concerns identified during construction and, if necessary, the status of all open and unresolved issues requiring further review and remediation prior to substantial completion and occupancy. A schedule of anticipated routine maintenance and repair relative to both the anticipated service life and published/contracted warranty period for each component of the building enclosure is also included in this documentation for review and use by the owner/end-user of the property upon initial occupancy and operation of the building.

- **Occupancy and Operations**

This phase begins at substantial completion and typically extends, at minimum, through the end of the warranty period established in the Owner/Contractor Agreement for both product and installation performance. BECx objectives included in this phase align generally with the objectives established in ASHRAE GL-0 and include:

- Verification of as-built performance and on-going compliance with the OPR
- Coordination and scheduling of seasonal or otherwise periodic non-destructive visual condition assessment of the building enclosure
- Evaluation, sampling, and laboratory or field testing as required to identify and resolve failures associated with non-conforming or otherwise substandard work that remained open and unresolved at substantial completion, or conditions arising as a result of accelerated weathering or premature failure of enclosure materials, components, and assemblies
- Coordination with owner-directed Retro (Re-) or Continuous Commissioning activities

Of particular value during this phase of the BECx process is the ability of the owner/end-user to call upon the institutional knowledge of the BECx service-provider to educate and train his/her staff in the design, construction, and intended performance of the building enclosure so that more specific, educated decisions can be made regarding routine condition assessment, warranty inspections, maintenance, and repair.

Summary

Building Enclosure Commissioning (BECx) is a holistic process developed with input from stakeholders in the real estate development, design, construction, and property management communities to supplement and strengthen the project delivery process and deliver higher performing buildings and structures. The need for BECx is, in part, a response to a demand in the marketplace for higher performing buildings and an increasing awareness among owners and developers regarding the changing role of the architect in the project delivery process, increasing compartmentalization of the design profession, and declining skill levels in the construction trades. The guidelines and standards developed by ASHRAE and ASTM to support Cx and BECx are the result of an open,, consensus-based process that included the development of several important documents, including ASHRAE GL-0, ASHRAE Standard 202, and ASTM E2813, *Standard Practice for Building Enclosure Commissioning.* ASTM E2813, like all consensus-based standards that are subject to periodic review and refinement, should be considered a "living document" that will evolve over time, and whose success or failure will ultimately be determined through actual application and use in the marketplace. That said, the real legacy of ASTM E2813 may prove to be the establishment of the Core Competencies embodied in its text – a step that promises to help fill the knowledge gaps that currently exist in the project delivery process. Over time, those same core competencies may also help serve as a catalyst toward the development of more uniform, widely available, and technically sound curriculum for students of architecture and engineering in building science, materials science, and the training necessary to deliver, rather than simply promise, truly sustainable buildings and structures.

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Since joining WJE in 1996, Daniel Lemieux has successfully completed hundreds of projects in the area of building enclosure failure investigation, repair design, and architectural rehabilitation, including projects that have been recognized both locally and nationally for design and restoration excellence. He has authored, coauthored, and peer reviewed a wide range of technical papers on Building Enclosure *Commissioning* (BECx) and is Chairman of ASTM Sub-Committee E06.55, *Performance of Building Enclosures*, and the Task Group responsible for the development and the publication of ASTM E2813-12, *Standard Practice for Building Enclosure Commissioning*. Since 2005, Mr. Lemieux has served as an author, co-author, and contributing editor during the development of the Exterior Wall chapters of the web-based Whole Building Design Guide on behalf of the National Institute of Building Sciences (NIBS), and was a member of the original committee responsible for the development of the original *NIBS Guideline 3: Exterior Enclosure Technical Requirements for the Commissioning Process*. As Chairman of ASTM E06.55, Mr. Lemieux facilitated the establishment of a joint agreement between ASTM and NIBS to develop a Building Enclosure Commissioning Certification and Training Program, and served on the committee responsible for the development of ASHRAE Standard 202, *The Commissioning Process for Buildings and Systems*.

Mr. Lemieux is a licensed architect in Washington, DC, Virginia, Maryland, New York, and Georgia and holds a BS from the Georgia Institute of Technology.

Professional Affiliations

American Architectural Manufacturers Association (AAMA); American Institute of Architects (AIA); Association for Preservation Technology International (APT); ASTM International (ASTM) / ASTM Sub-Committee E06.55 - Exterior Walls, Chairman; Construction Specifications Institute (CSI)

QUESTIONS

1. Setting aside both man-made and natural disasters, what are the three most common threats to the long-term durability, structural integrity, and performance of a building enclosure?

    a. Uncontrolled rainwater penetration

    b. Moisture-laden airflow and vapor diffusion (moisture ingress)

    c. Condensation potential

    d. All of the above

2. Which of the following is a direct consequence of the "compartmentalization" of the design profession and changing role of the architect in the project delivery process?

    a. Increasing demand for higher performing buildings

    b. Shift of design responsibility "downstream" into the construction industry and trades

    c. Increased risk of litigation

    d, All of the above

3. BECx can best be described today as:

    a. Good design practice

    b. Services and expertise I should expect from a qualified architect or engineer

    c. A holistic process intended to supplement and strengthen the project delivery process and deliver higher performing buildings

    d. All of the above

4. Optimum building performance begins at:

    a. Substantial completion

    b. Initial occupancy

    c. Conception

    d. Construction

5. Published guidelines and standards for BECx developed as a result of an open, consensus-based standards development process include:

    a. NIBS GL-3, Exterior Enclosure Technical Requirements for the Commissioning Process

    b. ASHRAE GL-0, The Commissioning Process

    c. ASHRAE Standard 202, Commissioning Process for Buildings and Systems

    d. ASTM E2813, Standard Practice for Building Enclosure Commissioning

    e. All of the above

    f. B, C , and D only

6. The publication of ASTM E2813 was significant because it established for the first time:

    a. Minimum enforceable levels of BECx

    b. A requirement for independent, third-party design reviews at milestone intervals throughout the Design Phase of the BECx process

    c. A "roadmap" for the development of an OPR that addresses performance expectations for energy efficient, environmentally conscious design and construction that is safe, secure, durable, sustainable, and serviceable through routine operation and maintenance

    d. A table of internationally recognized, consensus-based test standards to determine, quantifiably and at milestone intervals during construction, of the installed performance of a building enclosure satisfies the requirements of the OPR

    e. Minimum Core Competencies required of the BECx service-provider

    f .All of the above

7. True or False: The role and responsibilities of the BECx service-provider are not intended to supersede or otherwise replace the contractual obligations reserved specifically for the parties responsible for the design and construction of a building or structure, nor the duties assigned to those parties by applicable regulatory or statutory law.

    a. True

    b. False

8. The minimum core competencies of the BECx service-provider outlined in ASTM E2813 include:

   a. Performance Test Standards and Methodology

   b. Procurement and Project Delivery

   c. Building and Materials Science

   d. Contract Documents and Construction Administration

   e. All of the above

   f. A and C only

9. True or False: The minimum Core Competencies outlined in ASTM E2813 will form the basis of a new fully accredited ***ASTM/NIBS BECx Personnel Certification and Training Program*** and, over time, be further developed and refined to align with curricula currently being taught at colleges and universities in North America in building science, materials science, and the "physics" of climate-specific building enclosure performance.

   a. True

   b. False

10. True or False: The OPR is established during the Pre-Design phase and cannot be altered in any way during the Design and Pre-Construction phases of the BECx process.

   a. True

   b. False

11. Key components of the Cx/BECx Plan include:

   a, Roles and responsibilities of the Cx/BECx team members

   b. Cx/BECx schedule of activities

   c. Forms and templates

   d. Checklists

   e. Safety protocols

   f. All of the above

   g. A through D only

12. True or False: Detailing during the Design Phase to ensure alignment and continuity of the environmental control layers necessary for the effective management of heat, air, and moisture transfer is necessary to optimize building enclosure and total building performance.

    a. True

    b. False

13. Use of actual product profiles and configurations to convey design intent:

    a. Increases the enforceability of the contract documents

    b. Facilitates alignment and continuity of environmental control layers at building enclosure interfaces

    c. Should only be provided by the contractor during the development of shop drawings

    d. Minimizes the risk for Change Orders

    e. All of the above

    f. A, B, and D only

14. Pre-Construction laboratory and field-constructed mock-ups:

    a. Yield valuable insight regarding the influence of construction sequencing and coordination of trades on constructability and performance that is of significant value to the project team

    b. Result in further review and design refinement at a stage in the process when these changes can be addressed with minimal impact on overall project schedule and cost

    c. Should be required for all buildings, regardless of scale, significance, and intended use

    d. Should be considered strong candidates for qualification and exclusion as part of a "value-engineering" process

    e. All of the above

    f. A and B only

    g. A, B, and C only

15. Responsibilities of the BECx service-provider during the Construction Phase include:

    a. Coordination and scheduling of seasonal or otherwise periodic non-destructive visual condition assessment of the building enclosure

    B. Witness and document the construction and performance testing of all field-constructed, enclosure-related mock-ups

    c. Witness and document the field testing of representative enclosure materials, components, systems, and assemblies at milestone intervals during construction

    d. All of the above

    e. A and B only

16. True or False: The Occupancy and Operations phase of the BECx process offers the owner/end-user the opportunity to leverage the institutional knowledge of the BECx service-provider to educate and train his/her staff in the design, construction, and intended performance of the building enclosure and necessary steps for cost-effective routine condition assessment, maintenance, and repair.

    a. True

    b. False

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Instructions

Review the learning objectives below.

Read the AIA Learning Units article. Note: The complete article is avaliable at www.pci.org/elearning

Complete the online test. You will need to answer at least 80% of the questions correctly to receive the 1.0 HSW Learning Units associated with this educational program.

Learning Objectives:

1. Understand the history and development of Building Enclosure Commissioning (BECx).
2. Describe the BECx process.
3. Explain the requirements for BECx in ASTM E2813, *Standard Practice for Building Enclosure Commissioning*.
4. Discuss the relevance of BECx to the project delivery process, rolls and responsibilties of the project team, and verification of quantifiable building performance.

Questions: contact PCI Education Dept. at (312) 786-0300 or education@pci.org