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Standard Practice for Building Enclosure Commissioning[1]

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ε[1] NOTE—Editorial changes were made throughout in April 2015.

INTRODUCTION

Building Enclosure Commissioning (BECx) is a process that begins with the establishment of the Owner's Project Requirements (OPR) and endeavors to ensure that the exterior enclosure and those elements intended to provide environmental separation within a building or structure meet or exceed the expectations of the Owner as defined in the OPR. A fundamental understanding of the most current published edition of ASHRAE Standard 202, Commissioning Process for Buildings and Systems and ASTM E2947, Standard Guide for Building Enclosure Commissioning is recommended for optimal use and application of this practice.

1. Scope

1.1 This practice is intended to serve as a concise, authoritative, and technically sound practice for Building Enclosure Commissioning (BECx) that establishes two levels of BECx: *Fundamental* and *Enhanced* (refer also to Section 4).

1.2 The BECx process as defined in this practice includes the following phases and sub-phases:

1.2.1 Pre-design,
1.2.2 Design,
1.2.2.1 Schematic Design,
1.2.2.2 Design Development,
1.2.2.3 Construction Documentation,
1.2.3 Pre-Construction,[2]
1.2.4 Construction, and
1.2.5 Occupancy and Operations.

1.3 This practice includes a mandatory OPR Development Guideline (Annex A1) and requires the development of an OPR for both Fundamental and Enhanced BECx that addresses, at a minimum, the performance attributes and metrics included in Annex A1 of this practice.

1.4 This practice includes mandatory BECx Performance Testing Requirements (Annex A2) approved for use with this practice to evaluate the performance and durability of enclosure materials, components, systems, and assemblies.

1.5 This practice mandates independent, third-party design peer review during the Design Phase of both Fundamental and Enhanced BECx.

1.6 This practice recognizes that the OPR for exterior enclosure performance and environmental separation may exceed the baseline requirements of applicable building codes and standards and provides guidance for the development of an OPR based on the following attributes as defined in Annex A1 of this practice:

1.6.1 Energy,
1.6.2 Environment,
1.6.3 Safety,
1.6.4 Security,
1.6.5 Durability,
1.6.6 Sustainability, and
1.6.7 Operation.

1.7 The terms "building enclosure" and "enclosure" as they appear in this practice refer collectively to all materials, components, systems, and assemblies intended to provide shelter and environmental separation between interior and exterior, or between two or more environmentally distinct interior spaces in a building or structure.

1.8 This practice establishes that the Building Enclosure Commissioning Provider (BECxP) refers specifically to the individual 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 (see 4.2).

[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.55 on Performance of Building Enclosures.

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[2] See 5.1.3, Pre-Construction Phase, which includes BECx activities that occur prior to contract award and the start of construction, and is included in ASHRAE Standard 202 and Guide E2947 as a sub-phase under the "Construction Phase" of the BECx process.

1.9 The role and responsibilities of the BECxP as defined by this practice 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 that may otherwise be assigned to those parties by applicable regulatory or statutory law.

1.10 This practice is not intended to warrant or otherwise guarantee the as-built or in-service durability, or both, and performance of enclosure materials, components, systems, and assemblies.

1.11 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.12 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method
C510 Test Method for Staining and Color Change of Single- or Multicomponent Joint Sealants
C522 Test Method for Airflow Resistance of Acoustical Materials
C724 Test Method for Acid Resistance of Ceramic Decorations on Architectural-Type Glass
C732 Test Method for Aging Effects of Artificial Weathering on Latex Sealants
C794 Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants
C1060 Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings
C1087 Test Method for Determining Compatibility of Liquid-Applied Sealants with Accessories Used in Structural Glazing Systems
C1153 Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging
C1193 Guide for Use of Joint Sealants
C1246 Test Method for Effects of Heat Aging on Weight Loss, Cracking, and Chalking of Elastomeric Sealants After Cure
C1258 Test Method for Elevated Temperature and Humidity Resistance of Vapor Retarders for Insulation
C1279 Test Method for Non-Destructive Photoelastic Measurement of Edge and Surface Stresses in Annealed, Heat-Strengthened, and Fully Tempered Flat Glass
C1294 Test Method for Compatibility of Insulating Glass Edge Sealants with Liquid-Applied Glazing Materials
C1371 Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers
C1522 Test Method for Extensibility After Heat Aging of Cold Liquid-Applied Elastomeric Waterproofing Membranes
C1549 Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer
C1601 Test Method for Field Determination of Water Penetration of Masonry Wall Surfaces
C1651 Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Flat Glass
C1652 Test Method for Measuring Optical Distortion in Flat Glass Products Using Digital Photography of Grids
D2203 Test Method for Staining from Sealants
D4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
D5957 Guide for Flood Testing Horizontal Waterproofing Installations
E90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
E283 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
E330 Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference
E331 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
E336 Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings
E488 Test Methods for Strength of Anchors in Concrete and Masonry Elements
E492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine
E514 Test Method for Water Penetration and Leakage Through Masonry
E576 Test Method for Frost/Dew Point of Sealed Insulating Glass Units in the Vertical Position
E596 Test Method for Laboratory Measurement of Noise Reduction of Sound-Isolating Enclosures
E631 Terminology of Building Constructions
E779 Test Method for Determining Air Leakage Rate by Fan Pressurization
E783 Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors
E795 Practices for Mounting Test Specimens During Sound Absorption Tests
E903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
E966 Guide for Field Measurements of Airborne Sound Attenuation of Building Facades and Facade Elements

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E997 Test Method for Evaluating Glass Breakage Probability Under the Influence of Uniform Static Loads by Proof Load Testing
E1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures
E1014 Guide for Measurement of Outdoor A-Weighted Sound Levels
E1050 Test Method for Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones and a Digital Frequency Analysis System
E1105 Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference
E1186 Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems
E1425 Practice for Determining the Acoustical Performance of Windows, Doors, Skylight, and Glazed Wall Systems
E1503 Test Method for Conducting Outdoor Sound Measurements Using a Digital Statistical Sound Analysis System
E1827 Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door
E1886 Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials
E1980 Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces
E1996 Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes
E2099 Practice for the Specification and Evaluation of Pre-Construction Laboratory Mockups of Exterior Wall Systems
E2178 Test Method for Air Permeance of Building Materials
E2179 Test Method for Laboratory Measurement of the Effectiveness of Floor Coverings in Reducing Impact Sound Transmission Through Concrete Floors
E2249 Test Method for Laboratory Measurement of Airborne Transmission Loss of Building Partitions and Elements Using Sound Intensity
E2264 Practice for Determining the Effects of Temperature Cycling on Fenestration Products
E2268 Test Method for Water Penetration of Exterior Windows, Skylights, and Doors by Rapid Pulsed Air Pressure Difference
E2319 Test Method for Determining Air Flow Through the Face and Sides of Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
E2353 Test Methods for Performance of Glazing in Permanent Railing Systems, Guards, and Balustrades
E2357 Test Method for Determining Air Leakage of Air Barrier Assemblies
E2359 Test Method for Field Pull Testing of an In-Place Exterior Insulation and Finish System Clad Wall Assembly
E2570 Test Methods for Evaluating Water-Resistive Barrier (WRB) Coatings Used under Exterior Insulation and Finish Systems (EIFS) or EIFS with Drainage
E2649 Test Method for Determining Argon Concentration in Sealed Insulating Glass Units Using Spark Emission Spectroscopy
E2947 Guide for Building Enclosure Commissioning
F1233 Test Method for Security Glazing Materials And Systems
F1642 Test Method for Glazing and Glazing Systems Subject to Airblast Loadings
F1869 Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride
F2170 Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes
F2420 Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood (Withdrawn 2014)[4]

2.2 *ASHRAE Guidelines:*[5]
ASHRAE 90.1 Map of Climate Zones
ASHRAE Standard 202 Commissioning Process for Buildings and Systems

2.3 *AAMA Standards:*[6]
AAMA 501.1 Standard Test Method for Water Penetration of Windows, Curtain Walls, and Doors Using Dynamic Pressure
AAMA 501.2 Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems
AAMA 501.4 Recommended Static Test Method for Evaluating Curtain Wall and Storefront Systems Subjected to Seismic and Wind-Induced Interstory Drifts
AAMA 501.5 Test Method for Thermal Cycling of Exterior Walls
AAMA 508-07 Voluntary Test Method and Specifications for Pressure Equalized Rain Screen Wall Cladding Systems
AAMA 1503 Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors, and Glazed Wall Sections
AAMA 1801 Voluntary Specification for the Acoustical Rating of Windows, Doors, and Glazed Wall Sections

[4] The last approved version of this historical standard is referenced on www.astm.org.
[5] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.
[6] Available from American Architectural Manufacturers Association (AAMA), 1827 Walden Office Square, Suite 550, Schaumburg, Illinois 60173-4268, http://www.aamanet.org.

2.4 *ANSI Standards:*[7]
ANSI S12.8 Methods for Determination of Insertion Loss of Outdoor Noise Barriers
ANSI S12.60 Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools
ANSI-ASHRAE 101 Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics

2.5 *CAN/CGSB Standards:*[8]
CAN/CGSB 149-GP-2MP Manual for Thermographic Analysis of Building Envelopes

2.6 *CEN Standards:*[9]
CEN 1063 Testing and Classification of Resistance Against Bullet Attack

2.7 *CSA Standards:*[10]
CSA-A123.21 Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane Roofing Systems

2.8 *CSI Standards:*[11]
Project Resource Manual and Manual of Practice

2.9 *GANA Test Methods:*[12]
GANA LD 100-06 Standard Test Method for Ball Drop Impact of Laminated Architectural Flat Glass
GANA TD 101-04 Standard Test Method for Center-Punch Fragmentation of Fully-Tempered Flat Glass
GANA LD 101-08 Standard Specification for Ball Drop Impact Resistance of Laminated Architectural Flat Glazing

2.10 *GSA Standards:*[13]
GSA TS-01 Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings

2.11 *ICC Publications:*[14]
International Building Code

2.12 *ISO Publications:*
ISO 9000

2.13 *NIJ Standards:*[15]
NIJ Std. 0108.01 Ballistic Resistant Protective Materials

2.14 *NFRC Standards:*[16]
NFRC 100 Procedure for Determining Fenestration Product U-Factors
NFRC 200 Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence
NFRC 300 Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems

2.15 *State Department (SD) Ballistic Standards:*[17]
SD-STD-01.01 Forced Entry and Ballistic Resistance of Structural Systems

2.16 *UL Standards:*[18]
UL 752 Standard of Safety for Bullet-Resisting Equipment

3. Terminology

3.1 *Definitions*—Refer to the most current edition of the following:[19]
3.1.1 ASHRAE Standard 202, Section 3, Definitions
3.1.2 Guide E2947
3.1.3 Terminology E631
3.1.4 AIA Architect's Handbook of Professional Practice
3.1.5 CSI Project Resource Manual and Manual of Practice

3.2 *Acronyms:*
3.2.1 *AAMA*—American Architectural Manufacturers Association
3.2.2 *A/E*—Architect/Engineer
3.2.3 *AIA*—American Institute of Architects
3.2.4 *ANSI*—American National Standards Institute
3.2.5 *AOR*—Architect-of-Record
3.2.6 *ASCE*—American Society of Civil Engineers
3.2.7 *ASHRAE*—American Society of Heating, Refrigerating and Air Conditioning Engineers
3.2.8 *BCA*—Building Commissioning Association
3.2.9 *BECxP*—Building Enclosure Commissioning Provider (aka "Agent" or "Authority")
3.2.10 *BECxT*—Building Enclosure Commissioning Team
3.2.11 *BOD*—Basis-of-Design
3.2.12 *CAN/CGSB*—Canadian General Standards Board
3.2.13 *CSA*—Canadian Standards Association
3.2.14 *CSI*—Construction Specifications Institute
3.2.15 *Cx*—Commissioning
3.2.16 *CxA*—Commissioning Agent (or "Authority")
3.2.17 *CxP*—Commissioning Provider
3.2.18 *EIS*—Energy Information System
3.2.19 *EMCS*—Energy Management and Control System
3.2.20 *EOR*—Engineer-of-Record

[7] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[8] Available from Canadian General Standards Board (CAN/CGSB), http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html.
[9] Available from European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium, http://www.cen.eu.
[10] Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, http://www.csa.ca.
[11] Available from Construction Specifications Institute (CSI), 110 South Union Street, Suite 100, Alexandria VA 22314, http://www.csinet.org.
[12] Available from Glass Association of North America (GANA), 800 SW Jackson St. Suite 1500, Topeka, KS 66612-1200, http://www.glasswebsite.org.
[13] Available from U.S. General Services Administration (GSA), One Constitution Square, 1275 First Street, NE, Washington, DC 20417, http://www.gsa.gov.
[14] Available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001, http://www.iccsafe.org.
[15] Available from National Institute of Justice (NIJ), 810 7th St., NW, Washington, DC 20531, http://nij.gov.
[16] Available from National Fenestration Rating Council (NFRC), 6305 Ivy Lane, Suite 140, Greenbelt, MD 20770, http://www.nfrc.org.
[17] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.
[18] Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, http://www.ul.com.
[19] Selection, interpretation, application, and use of the terminology contained in these documents shall be at the sole discretion of the BECxP. Reconciliation of conflicts in terminology or the definition of terms that may exist among or between these documents shall be the sole responsibility of the BECxP, subject to review and final approval by the AOR and Owner.

3.2.21 *GANA*—Glass Association of North America

3.2.22 *GSA*—United States General Services Administration

3.2.23 *HVAC*—Heating, Ventilation, and Air Conditioning

3.2.24 *IAQ*—Indoor Air Quality

3.2.25 *IEQ*—Indoor Environmental Quality

3.2.26 *LEED*—Leadership in Energy and Environmental Design (trademark[20])

3.2.27 *NASFA*—National Association of State Facilities Administrators

3.2.28 *NEBB*—National Environmental Balancing Bureau

3.2.29 *NIBS*—National Institute of Building Sciences

3.2.30 *NFRC*—National Fenestration Rating Council

3.2.31 *O&M*—Operations and Maintenance

3.2.32 *OPR*—Owner's Project Requirements

3.2.33 *RCx*—Retro-Commissioning

3.2.34 *ReCx*—Re-Commissioning

3.2.35 *RFI*—Request For Information

3.2.36 *RFP*—Request For Proposals

3.2.37 *RFQ*—Request For Qualifications

3.2.38 *TAB*—Testing, Adjusting, and Balancing

3.2.39 *USDHS (or DHS)*—U.S. Department of Homeland Security

3.2.40 *USDOD (or DOD)*—U.S. Department of Defense

3.2.41 *USDOE (or DOE)*—U.S. Department of Energy

3.2.42 *USDOS (or DOS)*—U.S. Department of State

3.2.43 *USGBC*—U.S. Green Building Council

3.2.44 *VA*—U.S. Department of Veterans Affairs

4. Summary of Practice

4.1 This practice establishes two levels of BECx: *Fundamental and Enhanced*.

4.1.1 *Fundamental BECx*—Architecture or engineering-related technical services, or both, performed on behalf of the Owner by the BECxP and summarized as follows:

4.1.1.1 BECxP engagement during the *Design Phase* of the BECx process, but no later than commencement of the Design Development sub-phase;[21]

4.1.1.2 Review and documentation of the preliminary OPR developed during the Pre-Design Phase of the BECx process;[22]

4.1.1.3 Identification of the scope and recommended budget for the BECx process and development of a preliminary BECx Plan;[23]

4.1.1.4 Technical assistance and documentation during the development of the BOD, contract documents, project-specific BECx specification section, and final OPR during the Design Phase of the BECx process, including completion of a minimum of one independent, third-party design peer review of enclosure-related construction document drawings and specifications in a manner that will allow for timely review and consideration by the AOR prior to solicitation and contract award. The project-specific BECx specification section establishes the roles and responsibilities of the contractor and individual members of the construction team in the context of the BECx process, including a summary of required pre-construction laboratory and field performance test standards and methodology for enclosure-related materials, components, systems, and assemblies adopted from Annex A2 of this practice and further defined by the AOR in the approved contract document drawings and specifications;

4.1.1.5 Development of a final BECx Plan that includes an outline of the BECx process, roles and responsibilities of the BECxP and individual members of the BECx team, and the methodology established to verify and document compliance of the as-built construction with the requirements of the approved contract documents. The BECx Plan shall be developed to align with the requirements of the BECx section of the project specifications, and;

4.1.1.6 Direct and substantive participation[24] by the BECxP during the Pre-Construction, Construction, and Occupancy & Operations phases of the BECx process, including pre-construction laboratory and field performance testing as required in Annex A2 for *Fundamental BECx*.

4.1.2 *Enhanced BECx*—Architecture or engineering-related technical services, or both, performed on behalf of the Owner by the BECxP in accordance with the requirements of *Fundamental BECx*, but with the following additional requirements:

4.1.2.1 BECxP engagement during the *Pre-Design Phase* of the BECx process, but no later than commencement of the Schematic Design sub-phase;

4.1.2.2 Technical assistance and documentation during the development of the preliminary OPR;

4.1.2.3 Technical assistance and documentation during the development of the BOD, contract documents, project-specific BECx specification section, and final OPR during the Design Phase of the BECx process, including completion of a minimum of three independent, third-party design peer reviews[23] of enclosure-related construction document drawings and specifications in a manner that will allow for timely review and consideration by the AOR prior to solicitation and contract award, and;

4.1.2.4 Direct and substantive participation[25] (see 4.2) by the BECxP during the Pre-Construction, Construction, and Occupancy and Operations phases of the BECx process, including pre-construction laboratory and field performance testing as required in Annex A2 for *Enhanced BECx*.

[20] LEED is a trademark held by the U.S. Green Building Council.

[21] Typically characterized by the AOR as "50 %" completion of the Construction Documents, subject to review and concurrence by the Owner and BECxP.

[22] Including retroactive development of a written OPR in circumstances where a formal OPR may not exist or otherwise was not fully developed during the Pre-Design Phase of the BECx process as defined by ASHRAE Standard 202 and Guide E2947.

[23] The BECx Plan shall be as defined by ASHRAE Standard 202 and Guide E2947.

[24] As outlined in ASHRAE Standard 202 and Guide E2947, unless otherwise defined in this practice.

[25] As defined in ASHRAE Standard 202 and Guide E2947.

4.2 This practice establishes that the BECxP shall assemble a team (BECxT) that, at a minimum, demonstrates a level of proficiency in the core competencies listed below that meet or exceed the requirements of building codes, standards, guidelines, and regulations applicable to or otherwise voluntarily adopted by the Owner to govern enclosure-related design, construction, integration, and performance:

4.2.1 *BECxT Core Competencies:*

4.2.1.1 *Building and Materials Science,* including, at a minimum, demonstrated knowledge of the:

(1) Principles associated with heat transfer via conduction, convection, radiation, and air infiltration/exfiltration;

(2) Principles associated with moisture storage and transport via gravity, diffusion, convection, capillary action, absorbed flow, and osmosis; and

(3) 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.

4.2.1.2 *Procurement and Project Delivery,* including, at a minimum, demonstrated knowledge of the:

(1) Influence of the project delivery method[26] selected by the Owner on the scope, adaptation, implementation, and cost of the BECx process as defined in this practice;

(2) Influence of the number and type of contracts[27] established between the Owner and the design and construction teams on the role and responsibilities of the BECxP and individual members of the BECx team;

(3) 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;

(4) 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 BECxP, the range and technical depth required of the BECx team, and the anticipated scope and cost of the BECx process.

4.2.1.3 *Contract Documents and Construction Administration,* including, at a minimum, demonstrated knowledge of the:

(1) Interrelationship and commonly understood hierarchy that exists between Procurement Documents, Contract Documents, Contract Drawings and Specifications[28] developed during the Design Phase of the BECx process, as well as submittals and legally binding Instruments of Change[28] 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;

(2) Influence of enclosure-related design, detailing, and integration[29] on total building performance, including at a minimum consideration of the performance attributes listed in 1.5 and Annex A1 of this practice;

(3) 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;

(4) 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;

(5) 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.

4.2.1.4 *Performance Test Standards and Methodology,* including, at a minimum, demonstrated knowledge of the:

(1) Pre-construction laboratory and field-applied test standards and methodology referenced in this practice (see Annex A2) and their intended use and application[30] in evaluating the durability, performance, constructability, and anticipated service-life of enclosure-related materials, components, systems, and assemblies;

(2) Importance of establishing appropriate and quantifiable thresholds of performance and clear and unambiguous definitions of failure[31] for enclosure-related materials, components, systems, and assemblies to validate the OPR and BOD, and to allow for proper enforcement of the contract documents;

(3) 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;

(4) 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;

(5) 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

[26] Including, but not limited to: Design-Build; Design-Bid-Build; Design-Negotiate-Build; Construction Management, and; Owner-Build as defined by CSI Project Resource Manual and Manual of Practice.

[27] Including, but not limited to Single-Prime Contract and Multiple-Prime Contracts, with basis-of-payment provisions that may include: Stipulated/Lump Sum; Cost-Plus Fee; Fixed Fee, and; Guaranteed Maximum Price, with penalties, bonuses, and incentives for early completion of the work and liquidated damages for any delays in substantial or final completion of the project.

[28] As defined by the Construction Specifications Institute (CSI).

[29] Including, but not limited to integration with base building structural and environmental control systems.

[30] Including the limitations associated with each test standard.

[31] Including remedial action required in the event of failure and the nature and extent of re-testing necessary to verify compliance of the repair(s) with the requirements of the contract documents.

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;

(6) 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.

5. Procedure

5.1 This practice establishes that the BECx process shall be as outlined in ASHRAE Standard 202 and Guide E2947 and include, at a minimum, the following:

5.1.1 *Pre-Design Phase:*[32]

5.1.1.1 Attend a project planning conference ("Kick-Off Meeting");

5.1.1.2 Review the functional and programmatic requirements for the project established by the Owner and AOR;

5.1.1.3 Review and discuss factors influencing enclosure design, construction, long-term durability, serviceability, and performance with the Owner and AOR (if retained), including at a minimum (see also Annex A1):

(1) Anticipated construction type, importance factor, and occupancy/use classification;

(2) Geographic location and climate;

(3) Site orientation, massing, and options for enclosure material selection, integration, and relative distribution at each building exposure that will consider:

(a) Identification and apportionment of initial enclosure costs;

(b) Occupant comfort, productivity, and rate of return on initial investment;

(c) Enclosure long-term durability and performance;

(d) Costs associated with routine maintenance and energy use;

(e) Sustainable design objectives with long-term durability and performance;

(f) Optimize acoustical requirements; and

(g) Safety and security requirements.

(4) Consideration of exemplars that may exist in the same region or climate for which actual as-built enclosure performance can be quantifiably evaluated.

5.1.1.4 Provide technical assistance to the Owner during the development of a written OPR for enclosure materials, components, systems, and assemblies in accordance with Annex A1 of this practice,[33] including at a minimum an evaluation of the interrelationship between the following performance attributes and the relative influence of each on enclosure durability, performance, and total cost of ownership:

(1) Energy

(2) Environment

(3) Safety

(4) Security

(5) Durability

(6) Sustainability

(7) Operation

5.1.1.5 Provide a summary of the preliminary BECx Plan scope and budget to the Owner.

5.1.2 *Design Phase:*[34]

5.1.2.1 Review and document the OPR[35] and preliminary BECx Plan developed during the Pre-Design phase of the BECx process;

5.1.2.2 Review and provide technical assistance during the development of the preliminary enclosure BOD;[25]

5.1.2.3 Provide or otherwise coordinate the completion of an independent, third-party design peer review of enclosure-related construction document drawings and specifications based on the following sub-phases of the design process:[25]

(1) Schematic Design[36]

(2) Design Development[36]

(3) Construction Documents[37]

5.1.2.4 Update, refine, and document the OPR, enclosure BOD, and BECx Plan at the conclusion of each sub-phase of the design process;

5.1.2.5 Establish appropriate and quantifiable enclosure-related performance metrics, test standards, and test methodology in accordance with Annex A2 for incorporation into the contract documents,[23] including:

(1) Preconstruction laboratory mockups;

(2) Field-constructed "off-structure" mockups;

(3) Field-constructed "on-structure," first-installation mockups;

(4) Field testing at milestone intervals during construction;

(5) Post-occupancy evaluation and performance testing.

5.1.2.6 Provide a formal, written response to the position(s) taken by the AOR and other contracted parties to the project in response to BECxP comments and recommendations, including BECxP recommendations not accepted by the AOR and a summary discussion of the relative advantages, disadvantages, and potential risks associated with each of those decisions on building enclosure durability, performance, and total cost of ownership.[38]

5.1.2.7 Document the Design Phase OPR, enclosure BOD, and BECx Plan for review and approval by the Owner.

5.1.3 *Pre-Construction Phase:*

5.1.3.1 Attend a Pre-Bid Conference to review the BECx specification with prospective bidders;

[32] The *Pre-Design Phase* is the BECxP *minimum point-of-engagement* required to qualify as *Enhanced* BECx under this practice. Refer to ASHRAE Standard 202 and Guide E2947 for additional steps associated with this phase of the BECx process.

[33] Refer also to Guide E2947 for additional information regarding development of the OPR document.

[34] The *Design Phase* is the BECxP *minimum point-of-engagement* required to qualify as *Fundamental* BECx under this practice. Refer to ASHRAE Standard 202 and Guide E2947 for additional steps associated with this phase of the BECx process.

[35] Including retro-active development of a written OPR document based on input provided by the Owner in circumstances where a formal written OPR may not exist but is required to qualify as Fundamental BECx under this practice.

[36] Required to qualify for *Enhanced* BECx under this practice (optional for *Fundamental* BECx).

[37] Required to qualify for both *Fundamental* and *Enhanced* BECx.

[38] Documentation shall be provided as part of the updated OPR.

5.1.3.2 Review and assist with the evaluation of enclosure-related bidder requests for information or clarification and assist with the development of Addenda as appropriate;

5.1.3.3 Review and assist with the evaluation of enclosure-related contractor/subcontractor bids, including at a minimum:

(1) Scheduling, phasing, and coordination of trades;

(2) Quality Assurance (QA) and Quality Control (QC) programs;

(3) Qualifications and Exclusions; and

(4) Substitutions and "Value Engineering" options.

5.1.3.4 Document the Pre-Construction Phase OPR, enclosure BOD, and BECx Plan for review and approval by the Owner.

5.1.4 *Construction Phase:*[39]

5.1.4.1 Technical assistance during the review of enclosure-related shop drawings and technical submittals for compliance with the contract documents;

5.1.4.2 Direct and substantive participation[25] in a Pre-Construction Meeting and Pre-Installation Meetings with the GC, CM, and enclosure-related subcontractors and trades[40] to review and document, at a minimum:

(1) Final approved OPR, enclosure BOD, and BECx Plan;

(2) Status of all outstanding shop drawings and technical submittals;

(3) Schedule, phasing, and coordination of enclosure-related subcontractors and trades;[41]

(4) GC, CM, subcontractor, and enclosure-related trade QA, QC, and safety programs;[42]

(5) Subcontractor qualifications, exclusions, and conditions associated with the construction of a fully integrated building enclosure that may influence product, material, or installation warranties;

(6) Test standards and methodologies, performance thresholds, appropriate interpretation of test results, and definitions of failure required in the contract documents;[43]

(7) On-site construction observation and documentation protocol established for the timely identification and remediation of hidden/concealed or otherwise unanticipated conditions in the field, enclosure-related product or installation defects, and non-conforming work;

(8) Modification or refinement of enclosure-related detailing, fabrication, installation requirements, or sequencing and coordination of trades, or a combination thereof, arising from pre-construction mock-up assembly and testing.

5.1.4.3 Direct and substantive participation[25] during in-plant QA and QC reviews including, at a minimum, review and documentation of:

(1) Industry standard quality control criteria that may be applicable to the procurement or manufacture, or both, of the materials, components, systems, and assemblies specified for the project;[44]

(2) Methodology established to identify, track, and remediate, at milestone intervals during production, all defective and nonconforming work;

(3) Product or project-specific in-house technical training programs;

(4) In-house performance testing capabilities available for application to completed components and assemblies at milestone intervals during production.

5.1.4.4 On-site construction observation and documentation, including:

(1) Periodic observation, evaluation, and documentation of enclosure-related work in progress at representative locations on the project for compliance with the contract documents;[45]

(2) Development and distribution of field observation reports, field test reports, and related documentation as required for timely and effective review and remedial action by the GC, CM, and appropriate subcontractors and trades;[46]

(3) Coordination of and attendance at regularly scheduled BECx meetings with the GC, CM, and appropriate subcontractors and trades;

(4) Review and documentation of enclosure-related field performance testing at milestone intervals throughout construction[47] for compliance with the requirements of the contract documents,[48] including at a minimum:

(a) Review and documentation of the design and construction of all field-constructed test chambers and verification of current calibration[49] of all test equipment as required by the governing industry standard for the test method specified;

(b) Review and clarification of test procedures and methodology, performance thresholds, and definition(s) of "non-compliance" or "failure" as required in the contract documents.

(5) Review and documentation of modifications to or further refinement of the contract document drawings,

[39] Reference ASHRAE Standard 202 and Guide E2947 for additional information.

[40] Including, but not limited to, meetings in preparation for pre-construction laboratory or field-constructed, or both, mock-ups, "first installation" mock-ups, and actual construction in the field.

[41] Including, but not limited to, review and coordination of approved shop drawings for accuracy, completeness, and coordination with adjacent trades at enclosure interface conditions.

[42] Including, but not limited to, in-plant performance testing capabilities during production and milestone evaluation forms, checklists, and similar documentation intended to support both off-site fabrication and on-site field quality control programs.

[43] Including anticipated schedule for field testing and required coordination of trades to fully complete the work at each test specimen prior to testing.

[44] Examples include inspection or quality control criteria, or both, established by AAMA, the Portland Cement Association, and similar organizations that are in compliance with ISO 9000 and may be already required contractually or otherwise have been adopted for use by the supplier/manufacturer to which this practice is applied.

[45] The number and frequency of site visits required will vary based upon the complexity of the project and nature/extent of the work-in-progress and shall be determined at the sole discretion of the BECxP, subject to review and approval by the Owner.

[46] The BECxP shall develop, periodically update, and maintain a summary "log" of issues and concerns identified during the Construction Phase of the BECx process, and the actions taken by the construction team to address or otherwise remediate missing or non-conforming work.

[47] Refer to Annex A1 and the appropriate Appendix section for detailed information regarding recommended test standards and methodology.

[48] Including coordination with GC/CM project schedule and required sequencing, and coordination of trades.

[49] Includes both project-specific calibration in the field before testing and confirmation of any annual equipment calibration that may be required by appropriate/applicable industry or trade standards.

specifications, and approved shop drawings arising from field testing or unanticipated conditions encountered in the field during construction, or both.

5.1.4.5 Development and distribution of the BECx project closeout documents, including at a minimum:

(1) A summary outline or table listing all "open" or otherwise unresolved/undocumented remediation activities to address nonconforming work identified by the BECxP, AOR, or construction team, or a combination thereof; and

(2) Paper or electronic copies or both of all relevant, enclosure-related documentation and correspondence prepared by the BECxP for the Owner, AOR, or construction team, or a combination thereof.

(3) Guideline for routine evaluation and maintenance.

5.1.5 *Occupancy and Operations Phase:*[39]

5.1.5.1 Attend an Occupancy and Operations Planning Meeting with the owner/end user and representatives of the property management and building engineering team to review, at a minimum:

(1) Enclosure design, construction, installation, and performance testing history;

(2) Location and status of "open" or otherwise unresolved/undocumented remediation activities to address nonconforming work identified during construction and documented at substantial completion of the project;

(3) Estimated schedule for routine evaluation and maintenance.

5.1.5.2 Perform a limited (nondestructive) visual condition survey, performance testing, and qualitative assessment of enclosure-related materials, components, systems, and assemblies at milestone intervals during applicable warranty periods as outlined in the BECx schedule for routine evaluation and maintenance, or as requested by the Owner based on in-service performance;

5.1.5.3 Develop recommendations as required to re-establish enclosure-related durability, integration, and performance to a level consistent with the original OPR, BOD, and contract documents;

5.1.5.4 Develop recommendations as required to modify or otherwise improve enclosure-related durability and performance for consistency with a new or otherwise modified OPR at the discretion of the Owner to accommodate a change in the use, occupancy, classification, size, or configuration of a building or structure (or portions thereof).

6. Significance and Use

6.1 This practice is intended to serve as a concise, authoritative, and technically sound practice for Building Enclosure Commissioning (BECx) that is based upon:

6.1.1 The Owner Project Requirements;

6.1.2 Clearly defined and enforceable levels of BECx; and

6.1.3 Minimum core competencies required of the BECxP and associated service-providers[28] (see 4.2) to qualify as *Fundamental* or *Enhanced* BECx under this practice.

6.2 This practice is suitable for use as an independently applied standard for new buildings and structures, or as part of a more broadly based Total (or "Whole") Building Commissioning Program.

7. Keywords

7.1 ASHRAE; BECx; building; commissioning; documentation; enclosure; envelope; evaluation; exterior; functional; independent; inspection; LEED; mock-up; NIBS; observation; performance; quality; quantifiable; risk; service life; sustainable; testing; validation; verification

ANNEXES

(Mandatory Information)

A1. OPR DEVELOPMENT GUIDELINE

A1.1 The OPR is a written document that includes the programmatic, aesthetic, and functional performance requirements of a building or structure and the expectations of the Owner relative to its intended use, occupancy, operation, and service-life. The preliminary OPR developed during the *Pre-Design* phase of the BECx process establishes the basis for the development of a BOD and construction contract documentation,[50] and is subject to modification and further refinement only during the *Design* and *Pre-Construction* phases of the BECx process. Upon written acceptance by the Owner, the final OPR[51] and approved construction contract documents establish a baseline against which durability, performance, and total cost of ownership of a building or structure can reasonably be evaluated by the Owner at substantial completion of *Construction*, and throughout the *Occupancy & Operations* phase of the BECx process. (See also ASHRAE Standard 202 and Guide E2947 for additional information.)

A1.1.1 Development of the OPR must include, at a minimum, documented and verifiable consideration of the following attributes:

(1) Energy

[50] Including, but not limited to, construction document drawings and specifications as defined by CSI and developed by the AOR during the three sub-phases of the Design Phase as defined by this practice.

[51] As reflected in or otherwise limited to the requirements of the final construction contract documents developed by the AOR and approved by the Owner.

(2) Environment
(3) Safety
(4) Security
(5) Durability
(6) Sustainability
(7) Operation

NOTE A1.1—See also the U.S. Energy Independence and Security Act (EISA), 2007.

A1.2 The following questions represent the minimum range of issues and concerns that must be considered under this practice during the development of the OPR to determine the level of commissioning and functional performance testing required for a building or structure.

A1.2.1 What is the intended use, classification, anticipated construction type, and importance factor of the building or structure?

A1.2.1.1 *Use and Occupancy Classification:*
(1) Assembly Group A
(2) Business Group B
(3) Educational Group E
(4) Factory Group F
(5) High-Hazard Group H
(6) Institutional Group I
(7) Mercantile Group M
(8) Residential Group R
(9) Storage Group S
(10) Utility and Miscellaneous Group U

NOTE A1.2—Use and Occupancy classification as defined in Chapter 3 of the International Building Code.

A1.2.1.2 *Construction Type:*
(1) Types 1 and 2
(2) Type 3
(3) Type 4
(4) Type 5

NOTE A1.3—Construction type as defined in Chapter 3 of the 2003 International Building Code (Type 1 and 2 – building materials are non-combustible, Type 3 – exterior wall material is non-combustible and interior elements are any material permitted by building code, Type 4 – heavy timber construction, Type 5 – any building materials permitted by building code).

A1.2.1.3 *Importance Factor:*
(1) Occupancy category
(2) Seismic use group
(3) Seismic factor
(4) Snow factor
(5) Wind factor

A1.2.2 What is the anticipated or minimum required service life for the intended use and occupancy of the building or structure?

A1.2.2.1 0–24 years
A1.2.2.2 25–49 years
A1.2.2.3 50–74 years
A1.2.2.4 75–100 years
A1.2.2.5 100+ years

A1.2.3 What is the geographic location and climate in which the building will function after substantial completion and occupancy for intended use? (Refer to ASHRAE 90.1.)

A1.2.3.1 Hot-humid
A1.2.3.2 Mixed-humid
A1.2.3.3 Hot-dry
A1.2.3.4 Mixed-dry
A1.2.3.5 Cold
A1.2.3.6 Frigid
A1.2.3.7 Subarctic
A1.2.3.8 Marine

A1.2.4 What is the anticipated maximum "summertime" and "wintertime" difference in temperature between interior and exterior?

A1.2.4.1 Cooling season ("summertime") temperatures in excess of 38.3°C (101°F)

A1.2.4.2 Cooling season ("summertime") temperatures between 23.9 and 37.8°C (75 and 100°F)

A1.2.4.3 Cooling season ("summertime") temperatures less than 23.9°C (75°F)

A1.2.4.4 Heating season ("wintertime") temperature less than -23.3°C (–10°F)

A1.2.4.5 Heating season ("wintertime") temperature between -23.3 and –12.2°C (–10 and 10°F)

A1.2.4.6 Heating season ("wintertime") temperature between –12.2 and –1.1°C (10 and 30°F)

A1.2.4.7 Heating season ("wintertime") temperature above –1.1°C (30°F)

A1.2.4.8 What is the summertime interior ambient temperature?

A1.2.4.9 What is the wintertime interior ambient temperature?

A1.2.5 What is the anticipated interior relative humidity during summer and winter time?

A1.2.5.1 Relative humidity less than 20 %
A1.2.5.2 Relative humidity between 21–30 %
A1.2.5.3 Relative humidity between 31–40 %
A1.2.5.4 Relative humidity between 41–50 %
A1.2.5.5 Relative humidity in excess of 51 %

A1.2.6 What is the anticipated building pressurization (building pressure compared to the exterior pressure)?

A1.2.6.1 Negative building pressurization

A1.2.6.2 Positive building pressurization greater than 0 Pa (0 psf) and less than or equal to 9.6 Pa (0.2 psf)

A1.2.6.3 Positive building pressurization between 9.6 and 23.9 Pa (0.2 and 0.5 psf)

A1.2.6.4 Positive building pressurization greater than 23.9 Pa (0.5 psf)

A1.2.7 What are the energy use, operational, and performance expectations for the project?

A1.2.7.1 Energy performance below ASHRAE 90.1 (most recent) minimum

A1.2.7.2 Energy performance to ASHRAE 90.1 (most recent) minimum

A1.2.7.3 Energy performance beyond ASHRAE 90.1 (most recent)

A1.2.8 Is the owner seeking certification under published guidelines for sustainable or otherwise environmentally conscious design, construction, and operation?[52]

A1.2.8.1 LEED Platinum

A1.2.8.2 LEED Gold

A1.2.8.3 LEED Silver

A1.2.8.4 LEED Certified

A1.2.8.5 Is the owner seeking additional LEED point(s) for BECx or pursuing similarly oriented objectives associated with energy conservation and environmentally-conscious design and construction?[53]

A1.2.9 Are the environmental separation layers intended to be readily accessible, serviceable, and consistent with the anticipated service life of the building?[54]

A1.2.9.1 Environmental separation layers are accessible

A1.2.9.2 Environmental separation layers are durable

A1.2.9.3 Environmental separation layers are both accessible and durable

A1.2.9.4 Environmental separation layers are neither accessible nor durable

A1.2.10 What are the fire protection requirements?

A1.2.10.1 Fire protection levels at code minimum

A1.2.10.2 Fire protection levels beyond code minimum

A1.2.11 Are there specific structural, seismic, security, forced entry or blast-resistance requirements for this project?

A1.2.12 Are there specific acoustical requirements? At a minimum, identify if project is in proximity to:

A1.2.12.1 Airports (within 8 km [5 miles] or 65 dBA or higher contour curve),

A1.2.12.2 Freeways, fire stations, sports arenas, racetracks (within 0.3 km [1000 ft]), and

A1.2.12.3 Active railways, helicopter pads (within 0.6 km [3000 ft])

A1.2.13 Are there specific operation and maintenance constraints (for example, is this a No-Time-Loss facility)?

A1.2.14 What is the project delivery method?

A1.2.14.1 Design-bid-build

A1.2.14.2 At-risk construction manager or multiple prime

A1.2.14.3 Fast-track or design-build

A1.2.14.4 Other

A1.2.15 What is the anticipated project schedule?

A1.2.16 What is the Owner's expectation regarding the BECx process and its ability to mitigate the risks associated with improperly managed heat/air/moisture transfer? The answer to this question, will, by definition, include a discussion regarding the Owner's tolerance for the risk of uncontrolled rainwater penetration and condensation (see Annex A2), and will be influenced by climate and the intended use and occupancy of the building.

A1.2.17 **What is the budget for the BECx process including functional performance testing?**

A1.3 Goals and objectives established by the Owner in response to these and related questions, and the overlapping consequences and outcomes identified by the BECxP[55] as a result of the OPR development process, shall be documented by the BECxP during the Pre-Design phase of the BECx process as the initial OPR, then further updated and refined as necessary during the Design and Pre-Construction phases to align with the final BOD and respond to issues and concerns that may be revealed during pre-construction laboratory or field-constructed mock-up testing, or both.

A1.4 Based upon the final OPR and BOD established using Annex A1, the Owner, BECxP and Architect/Engineer-of-Record shall determine an appropriate level of BECx and functional performance testing required for the project using Annex A2 to this practice.

[52] Including, but not limited to, published guidelines available from the U.S. Green Building Council, Green Globes, and similarly aligned organizations that may be voluntarily adopted, in whole or in part, by the Owner for a given building or structure.

[53] Including, but not limited to, published guidelines available from the United States Green Building Council (USGBC), Green Globes, and similarly aligned organizations that may be voluntarily adopted, in whole or in part, by the Owner for a given building or structure.

[54] Answers to these questions may not be fully obtained during the Pre-Design phase and will require follow-up inquiry during the design phase.

[55] And Architect/Engineer-of-Record and associated members of the design team if retained by the owner to assist with this process.

A2. BECx PERFORMANCE TESTING REQUIREMENTS

A2.1 Table A2.1 includes an outline of the minimum required tests for *Fundamental* and *Enhanced* BECx as defined by this practice. **The minimum number of tests required to achieve *Fundamental* or *Enhanced* BECx refers to the number of tests *per unique type of enclosure element* as defined by the AOR in consultation with the BECxP, and should be a function of the priorities established in the OPR, including but not limited to the performance attributes and budget considerations (A1.2.17) included in Annex A1 of this practice. Test requirements apply only as appropriate to the materials, components, and systems specified for the enclosure.**

A2.2 Mandatory field tests are indicated in Table A2.1 with a check mark ("✔"), followed by the minimum number of tests required to achieve either *Fundamental* or *Enhanced* BECx.

TABLE A2.1 BECx Performance Testing Requirements

NOTE 1—Areas of the table marked by leaders (". . .") indicate test methods that are not applicable.

NOTE 2—"L" indicates that a job-specific laboratory test is required.

NOTE 3—"OL" indicates an optional laboratory test.

NOTE 4—"(OF)" indicates an optional field test.

NOTE 5—"(M)" indicates a laboratory pre-construction mock-up test included in or otherwise available for consideration as part of Practice E2099.

NOTE 6—"✓" indicates a mandatory field test followed by the minimum number of tests required in accordance with unique material, component, system, or assembly.

NOTE 7—"ref" indicates reference standard or guideline.

Property	Standard Designation	Title	Lab System Testing	Enhanced		Fundamental	
				Field Mockup Testing[A]	In-Situ Field Testing	Field Mockup Testing	In-Situ Field Testing
Acoustic Performance							
Acoustic performance	ASTM C423	Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method	OL	. . .	. . .	. . .	. . .
	ASTM E795	Practices for Mounting Test Specimens During Sound Absorption Tests	OL	. . .	. . .	. . .	. . .
	ASTM C522	Test Method for Airflow Resistance of Acoustical Materials	OL	. . .	. . .	. . .	. . .
	ASTM E492	Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine	OL	. . .	. . .	. . .	. . .
	ASTM E90	Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements	OL	. . .	. . .	. . .	. . .
	ASTM E1425	Practice for Determining the Acoustical Performance of Windows, Doors, Skylights, and Glazed Wall Systems	OL	. . .	. . .	. . .	. . .
	AAMA 1801	Voluntary Specification for the Acoustical Rating of Windows, Doors, and Glazed Wall Sections	OL	. . .	. . .	. . .	. . .
	ASTM E336	Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings	. . .	. . .	(OF)	. . .	(OF)
	ASTM E596	Test Method for Laboratory Measurement of Noise Reduction of Sound-Isolating Enclosures	OL	. . .	. . .	. . .	. . .
	ASTM E966	Guide for Field Measurements of Airborne Sound Insulation of Building Façades and Façade Elements	. . .	✓ (1X)	(OF)	(OF)	(OF)
	ASTM E1007	Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures	. . .	(OF)	(OF)	(OF)	(OF)
	ASTM E1014	Guide for Measurement of Outdoor A-Weighted Sound Levels	. . .	✓ (1X)	(OF)	(OF)	(OF)
	ASTM E1503	Test Method for Conducting Outdoor Sound Measurements Using a Digital Statistical Sound Analysis System	. . .	✓ (1X)	(OF)	(OF)	(OF)
	ASTM E1050	Test Method for Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones, and a Digital Frequency Analysis System	OL	. . .	. . .	. . .	. . .
	ASTM E2179	Test Method for Laboratory Measurement of the Effectiveness of Floor Coverings in Reducing Impact Sound Transmission Through Concrete Floors	OL	. . .	. . .	. . .	. . .

TABLE A2.1 *Continued*

Property	Standard Designation	Title	Lab System Testing	Enhanced		Fundamental	
				Field Mockup Testing[A]	In-Situ Field Testing	Field Mockup Testing	In-Situ Field Testing
	ASTM E2249	Test Method for Laboratory Measurement of Airborne Transmission Loss of Building Partitions and Elements Using Sound Intensity	OL	. . .	. . .	. . .	. . .
	ANSI S12.8	Methods for Determination of Insertion Loss of Outdoor Noise Barriers	. . .	(OF)	(OF)	(OF)	(OF)
	ANSI S12.60	Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools	OL	. . .	. . .	. . .	. . .
		Air Infiltration					
Air flow	ASTM E2319	Test Method for Determining Air Flow Through the Face and Sides of Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen	OL	. . .	. . .	. . .	. . .
Air leakage	ASTM E283	Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen	L (M)	. . .	. . .	. . .	. . .
	ASTM E779	Test Method for Determining Air Leakage Rate by Fan Pressurization	. . .	. . .	✓ (1X)	. . .	(OF)
	ASTM E1827	Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door	. . .	. . .	✓ (1X)	. . .	(OF)
	ASTM E783[B] *Opaque Walls*	Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors	. . .	✓ (1X)	✓ (1X)	✓ (1X)	✓ (1X)
	ASTM E783 *Windows*	Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors	. . .	✓ (1X)	✓ (2X)	✓ (1X)	✓ (1X)
	ASTM E1186	Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems	. . .	(OF)	✓ (1X)	(OF)	✓ (1X)
Air permeance	ASTM E2178	Test Method for Air Permeance of Building Materials	OL	. . .	. . .	. . .	. . .
	ASTM E2357	Test Method for Determining Air Leakage of Air Barrier Assemblies	OL	. . .	. . .	. . .	. . .
		Thermal Performance and Condensation Resistance					
Condensation resistance	AAMA 1503	Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors, and Glazed Wall Sections	OL[C] (M)	(OF)[D]	(OF)	(OF)	(OF)
Insulation	ASTM C1153	Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging	. . .	. . .	✓ (1X)[E]	. . .	✓ (1X)
Temperature index calculation/test	AAMA 501.5	Test Method for Thermal Cycling of Exterior Walls	OL (M)	(OF)	. . .	(OF)	. . .
Thermal performance	CAN/CGSB 149-GP-2MP	Manual for Thermographic Analysis of Building Envelopes	ref	. . .	. . .	. . .	. . .
Insulation	ASTM C1060	Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings	. . .	. . .	(OF)	. . .	(OF)
Dew point of IGU	ASTM E576	Test Method for Frost/Dew Point of Sealed Insulating Glass Units in the Vertical Position	. . .	(OF)	(OF)	(OF)	(OF)
Heat Loss	ANSI-ASHRAE 101	Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics	. . .	(OF)	(OF)	(OF)	(OF)
U factor	NFRC 100	Procedure for Determining Fenestration Product U-Factors	OL	. . .	. . .	. . .	. . .
	ASTM E2264	Practice for Determining the Effects of Temperature Cycling on Fenestration Products	OL	. . .	. . .	. . .	. . .

TABLE A2.1 *Continued*

Property	Standard Designation	Title	Lab System Testing	Enhanced		Fundamental	
				Field Mockup Testing[A]	In-Situ Field Testing	Field Mockup Testing	In-Situ Field Testing
		Water Penetration					
Water penetration	ASTM E331	Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference	L (M)	. . .	. . .	. . .	. . .
	ASTM E514	Test Method for Water Penetration and Leakage Through Masonry	OL	(OF)	(OF)	(OF)	(OF)
	ASTM C1601	Test Method for Field Determination of Water Penetration of Masonry Wall Surfaces	. . .	(OF)	(OF)	(OF)	(OF)
	ASTM D5957[F]	Guide for Flood Testing Horizontal Waterproofing Installations	. . .	(OF)	✓ (All horizontal surfaces)	(OF)	✓ (All horizontal surfaces)
Static water penetration	ASTM E1105	Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference	. . .	✓ (1X)	✓ (2X)	✓ (1X)	✓ (1X)
Dynamic water penetration	AAMA 501.1	Standard Test Method for Water Penetration of Windows, Curtain Walls, and Doors Using Dynamic Pressure	OL (M)	(OF)	✓ (1X)	(OF)	(OF)
	ASTM E2268[G]	Standard Test Method for Water Penetration of Exterior Windows, Skylights, and Doors by Rapid Pulsed Air Pressure Difference	OL	(OF)	(OF)	(OF)	(OF)
	AAMA 501.2	Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems	. . .	✓ (1X)	✓ (1X)	✓ (1X)	✓ (1X)
		Durability and Appearance					
Glazing stress testing	ASTM C1279	Test Method for Non-Destructive Photoelastic Measurement of Edge and Surface Stresses in Annealed, Heat-Strengthened, and Fully-Tempered Glass	OL	. . .	. . .	. . .	. . .
Glazing structural performance	ASTM E997	Test Method for Structural Performance of Glass in Exterior Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Destructive Methods	OL	(OF)	. . .	(OF)	. . .
	GANA LD 100-06	Standard Test Method for Ball Drop Impact of Laminated Architectural Flat Glass	OL	. . .	. . .	. . .	. . .
	GANA LD 101-08	Standard Specification for Ball Drop Impact Resistance of Laminated Architectural Flat Glazing	OL	. . .	. . .	. . .	. . .
	GANA TD 101-04	Standard Test Method for Center-Punch Fragmentation of Fully-Tempered Flat Glass	OL	. . .	. . .	. . .	. . .
Glazing material appearance and durability	ASTM C724	Test Method for Acid Resistance of Ceramic decorations on Architectural-Type Glass	OL	(OF)	. . .	(OF)	. . .
	ASTM C1651	Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Flat Glass	OL	(OF)	(OF)	(OF)	(OF)
	ASTM C1652	Test Method for Measuring Optical Distortion in Flat Glass Products Using Digital Photography of Grids	OL	(OF)	(OF)	(OF)	(OF)
	ASTM E2649	Test Method for Determining Argon Concentration in Sealed Insulating Glass Units Using Spark Emission Spectroscopy	OL	. . .	. . .	. . .	. . .
Adhesion and durability	ASTM C1258	Test Method for Elevated Temperature and Humidity Resistance of Vapor Retarders for Insulation	OL	. . .	. . .	. . .	. . .
	ASTM C1522	Test Method for Extensibility After Heat Aging of Cold Liquid-Applied Elastomeric Waterproofing Membranes	OL	. . .	. . .	. . .	. . .

TABLE A2.1 *Continued*

Property	Standard Designation	Title	Lab System Testing	Enhanced		Fundamental	
				Field Mockup Testing[A]	In-Situ Field Testing	Field Mockup Testing	In-Situ Field Testing
	ASTM D4541	Test Method for Pull-off Strength for Coatings Using Portable Adhesion Testers	. . .	✓ (1X)	✓ (1X)	✓ (1X)	(OF)
	ASTM E488	Test Methods for Strength of Anchors in Concrete and Masonry Elements	. . .	(OF)	✓ (1X)	✓ (1X)	✓ (1X)
	ASTM E2359	Test Method for Field Pull Testing of an In-Place Exterior Insulation and Finish System Clad Wall Assembly	. . .	✓ (1X)	✓ (1X)	✓ (1X)	✓ (1X)
	ASTM E2570	Test Methods for Evaluating Water-Resistive Barrier Coatings Used Under Exterior Insulation and Finish Systems or EIFS with Drainage	OL	. . .	. . .	. . .	. . .
Sealant durability	ASTM C794	Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants	OL	✓ (1X)	✓ (3X)	✓ (1X)	✓ (1X)
	ASTM C732	Test Method for Aging Effects of Artificial Weathering on Latex Sealants	OL	. . .	. . .	. . .	. . .
	ASTM C1087	Test Method for Determining Compatibility of Liquid-Applied Sealants with Accessories Used in Structural Glazing Systems	OL	. . .	. . .	. . .	. . .
	ASTM C1193, Appendix X1-Method A	Guide for Use of Joint Sealants: Field-Applied Sealant Joint Hand Pull Tab	. . .	✓ (1X)	✓ (1X)	✓ (1X)	✓ (1X)
	ASTM C1246	Test Method for Effects of Heat Aging on Weight Loss, Cracking, and Chalking of Elastomeric Sealants After Cure	OL	. . .	. . .	. . .	. . .
	ASTM C1294	Test Method for Compatibility of Insulating Glass Edge Sealants with Liquid-Applied Glazing Materials	OL	. . .	. . .	. . .	. . .
Sealant appearance	ASTM C510	Test Method for Staining and Color Change of Single- or Multicomponent Joint Sealants	OL	. . .	. . .	. . .	. . .
	ASTM D2203	Test Method for Staining from Sealants	OL	. . .	. . .	. . .	. . .
		Structural Performance					
Envelope deflection due to wind loading	ASTM E330	Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference	L (M)	(OF)	(OF)	(OF)	(OF)
Inter-story drift	AAMA 501.4	Recommended Static Test Method for Evaluating Curtain Wall and Storefront Systems Subjected to Seismic and Wind-Induced Interstory Drifts	OL (M)	. . .	. . .	. . .	. . .
Wind uplift	CSA-A123.21	Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane Roofing Systems	OL	(OF)	(OF)	(OF)	(OF)
		Rain Screen Pressure Equalization					
	AAMA 508-07	Voluntary Test Method and Specifications for Pressure Equalized Rain Screen Wall Cladding Systems	L	(OF)	. . .	(OF)	. . .
		Solar Optical Performance					
Solar Absorptance	ASTM E903	Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres (Withdrawn 2005)	OL	(OF)	(OF)	(OF)	(OF)
	NFRC 200	Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence	OL	. . .	. . .	. . .	. . .
Solar optical properties	NFRC 300	Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems	OL	. . .	. . .	. . .	. . .
	ASTM C1371	Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers	OL	(OF)	(OF)	(OF)	(OF)

TABLE A2.1 *Continued*

Property	Standard Designation	Title	Lab System Testing	Enhanced		Fundamental	
				Field Mockup Testing[A]	In-Situ Field Testing	Field Mockup Testing	In-Situ Field Testing
	ASTM C1549	Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer	OL	(OF)	(OF)	(OF)	(OF)
	ASTM E1980	Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces	OL	. . .	. . .	. . .	. . .
		Moisture Content					
Moisture content	ASTM F1869	Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride	OL	(OF)	(OF)	(OF)	(OF)
	ASTM F2170	Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes	OL	(OF)	(OF)	(OF)	(OF)
	ASTM F2420	Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood	OL	(OF)	(OF)	(OF)	(OF)
		Security					
Forced entry	ASTM F1233	Test Method for Security Glazing Materials and Systems	OL	(OF)	(OF)	(OF)	(OF)
	SD-STD-01.01	Forced Entry and Ballistic Resistance of Structural Systems	OL	(OF)	(OF)	(OF)	(OF)
Impact/ballistic resistance	ASTM E1886	Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials	OL	. . .	. . .	. . .	. . .
	ASTM E2353	Test Methods for Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades	OL	. . .	. . .	. . .	. . .
	ASTM E1996	Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris and Hurricanes	OL	. . .	. . .	. . .	. . .
	CEN 1063	Testing and Classification of Resistance Against Bullet Attack	OL	. . .	. . .	. . .	. . .
	NIJ Std. 0108.01	Ballistic Resistant Protective Materials	OL	. . .	. . .	. . .	. . .
	UL 752	Standard of Safety for Bullet-Resisting Equipment	OL	. . .	. . .	. . .	. . .
Blast	ASTM F1642	Test Method for Glazing and Glazing Systems Subject to Air Blast Loadings	OL	. . .	. . .	. . .	. . .
	GSA TS-01	Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings	OL	. . .	. . .	. . .	. . .

[A] Including both off-building and "first installation" on-building mockups.
[B] Typically performed in conjunction with Test Method E1105.
[C] A job-specific laboratory test may be recommended by the BECxP based on climate and enclosure designs with increased condensation risk (that is, thermal bridges across the enclosure including curtain walls incorporating fins or structural elements that extend through the thermal barrier).
[D] A modified AAMA 1503 test may be performed in the field.
[E] In conjunction with required water penetration resistance testing of roofing and as appropriate for specific roofing assembly.
[F] Depending upon roofing type and installation, Electronic Weak Detection (ELD) or Nuclear Radioisotopic Thermalization may also be considered to supplement or replace this evaluation.
[G] This test serves as an alternate to the Field Dynamic testing as listed in AAMA 501.1. The number of tests recommended do not align (are less then) AAMA 501.1 as this practice requires construction of a chamber to provide a differential pressure.

Optional field test methods are denoted by "(OF)."[56] Areas of the table marked by leaders (". . .") indicate test methods that are not applicable. Optional laboratory test methods are indicated by "OL" and can be applied at the discretion of the AOR and BECxP unless otherwise required by code.

[56] Optional at the discretion of the AOR and BECxP.

A2.3 **Selection, interpretation, application, and use of each test standard included in Table A2.1 shall be specified at the sole discretion of the AOR in direct consultation with the BECxP during the *Design Phase* of the BECx process, subject to final review and approval by the Owner. Specification and use of the individual test standards allowed under this practice will vary based upon the OPR and relative influence of the performance attributes and budget considerations (A1.2.17) listed in Annex A1 of this practice.**

A2.4 **Use of the optional test standards listed herein, or tests not specifically listed herein but determined by the AOR and BECxP to be appropriate for the evaluation of project-specific enclosure materials, components, systems, and assemblies, shall be specified at the sole discretion of the AOR, subject to final review and approval by the Owner.**

A2.5 "First-installation" mock-ups[57] are a minimum requirement of both *Fundamental* and *Enhanced* BECx. A pre-construction laboratory or on-site, "off-building" mock-up is a minimum requirement of *Enhanced BECx*. The purpose of both shall be to evaluate enclosure-related constructability and performance, with a specific emphasis on the required coordination of trades and sequencing of the work necessary to ensure that both the functional and integrated performance[58] of enclosure materials, components, systems, assemblies, and interfaces meets or exceeds the requirements of the contract documents.

A2.5.1 A first-installation field mock shall be provided for each major exterior enclosure system including:

(1) Each below grade underslab and vertical waterproofing system.

(2) Each type of horizontal waterproofing system enclosing occupied space below.

(3) Each substantially different type of vertical enclosure assembly included in the design.

(4) Each low-slope and steep-slope roofing assembly.

A2.5.2 Extent of each first-installation field mock-up shall include the interface of various materials and systems, both between various major assemblies (for example, the foundation waterproofing connection to a wall assembly) and between materials in an assembly (for example, the interface between window and wall).

(1) Wall first-installation mock-ups shall typically extend one full structural bay wide by one full story high plus additional height to connect to assemblies below and above and shall include a typical wall to interior floor slab connection. Mock-ups shall be a minimum of 100 square feet.

(2) Roof first-installation mock-ups shall include parapet or roof edge conditions and shall be a minimum of 100 square feet. Include typical pipe, dunnage and similar penetrations.

(3) Horizontal below-grade waterproofing and slab-on-grade first-installation mock-ups shall include edge conditions and shall be a minimum of 100 square feet. Include typical penetration details.

(4) Vertical below-grade waterproofing first-installation mock-ups shall include edge, termination and penetration details.

(5) Building expansion joints: Extent of expansion joint first-installation mock-ups shall be sufficient to include starting point at foundation, extending up vertical surfaces, across horizontal waterproofed surfaces and roofs and returning to foundation. Include each type of corner, intersection, transition and termination.

A2.6 Pre-construction laboratory mock-up testing shall be completed in accordance with Practice E2099, modified as required to respond to the performance objectives established in the OPR and included in the construction contract documents by the AOR, in consultation with the BECxP and subject to review and approval by the Owner. Test standards and methodology, minimum required performance thresholds, and clearly defined definitions of "failure" must be clearly defined and specified by the AOR during the *Design Phase* of the BECx process in order to ensure proper enforcement of the construction contract documents. Modification or further refinement of the OPR or construction contract document drawings and specifications that may become necessary[59] as a result of pre-construction mock-up testing shall be the sole responsibility of the AOR, subject to final review and approval by the Owner. Modification or further refinement of preliminary shop drawings and related information[60] that may become necessary as a result of pre-construction mock-up testing shall be the sole responsibility of the contractor, subject to final review and approval by the AOR and Owner.[61]

A2.7 Pre-construction laboratory mock-ups shall be scheduled to allow for potential modification or further refinement of the product design or fabrication, or both, of individual materials, components, systems, and assemblies that will comprise the building enclosure, and re-testing of the completed assembly to verify that the integrated performance of the mock-up meets or exceeds the requirements of the contract documents.

[57] "First installation" refers to the initial installation of specific enclosure materials, components, systems, or assemblies that will be tested in accordance with the contract documents, and if in compliance, may remain as part of the completed construction.

[58] *Functional performance* as defined by this practice refers to performance criteria established in the contract document specifications or otherwise published by the supplier/manufacturer for each of the individual materials, components, or systems specified for installation as part of the building enclosure. *Integrated performance* as defined by this practice refers to the performance of the fully integrated building enclosure after it has been constructed, including interface conditions between each of the individual materials, components and systems specified for installation as part of the building enclosure. Field testing shall be developed and systematically applied in a manner that allows for the accurate assessment of both relative to the requirements of the contract documents.

[59] Or otherwise are determined by the Owner to be in the best interests of the project.

[60] Including modifications to project schedule, sequencing, and coordination of the trades.

[61] It is recommended, though not required by this practice, that representatives of the suppliers, fabricators, sub-contractors, and trades responsible for the design, fabrication, construction, and integration of materials, components, systems, and assemblies to be included in all specified pre-construction mock-ups also hold a similar position or otherwise be substantively engaged during actual construction in the field.

A2.8 Unique performance test standards and methodology that may extend beyond the requirements of Table A2.1, but are determined by the AOR, BECxP, and Owner to be critical to the performance objectives and desired outcomes established in the OPR, shall be considered mandatory for *Enhanced BECx*. Such criteria may include, but not be limited to: acoustic and Radio Frequency (RF) isolation; chemical, biological, and radiation protection; electromagnetic interference shielding; resiliency and recovery time following a seismic event, hurricane, or other natural disaster; structural hardening, and similar requirements commonly associated with the Environment, Safety, and Security attributes included in Annex A1 of this practice.

A2.9 In the event that initial test results associated with either pre-construction mock-up or field testing at "milestone" intervals during construction fail to meet or exceed the minimum performance requirements established in the construction contract documents, further investigation of the failure(s) shall be completed at the direction of the contractor and AOR, in consultation with the BECxP and Owner. Requirements for additional testing shall be at the sole discretion of the AOR in consultation with the BECxP, subject to the limitations of the contract documents.

APPENDIX

(Nonmandatory Information)

X1. RELATED DOCUMENTS

NOTE X1.1—Selection, interpretation, application, and use of these documents, in whole or in part, during the development of an ECx Program shall be at the sole discretion of the ECxA, subject to review and acceptance by the architect/engineer of record and approval of the owner.

X1.1 ASHRAE/ANSI Guidelines and Standards

ASHRAE Guideline 1 (1996) The HVAC Commissioning Process

ASHRAE Guideline 1.1 (2007) HVAC&R Technical Requirements for the Commissioning Process

ASHRAE/ANSI Standard 105 Expressing and Comparing Building Energy Performance

ASHRAE/ANSI Standard 160 Criteria for Moisture-Control Design Analysis in Buildings

ASHRAE/ANSI Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings

ASHRAE/ANSI/IES Standard 189.1 Standard for the Design of High-Performance Green Buildings

X1.2 Building Commissioning Association (BCA) Standard

Building Commissioning Attributes (1999)

X1.3 Canadian Standards Association (CSA) Standard

Z320 (2010) Building Commissioning

X1.4 International Standards Organization (ISO) Standard

ISO 9000 Quality Management Systems - Fundamentals and Vocabulary

X1.5 American Society for Healthcare Engineering (ASHE) Guidelines

Health Facility Commissioning Guidelines

Guidelines for Design and Construction of Health Care Facilities

Health Facility Design Information Checklist

X1.6 ASTM Standard

E1557 Classification for Building Elements and Related Sitework (UNIFORMAT II)

X1.7 United States Federal Energy Legislation

U.S. Energy Independence and Security Act (EISA) 2007

X1.8 United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) Green Building Rating System

LEED for New Construction and Major Renovations

LEED for Healthcare

X1.9 Whole Building Design Guide (www.wbdg.org)

Building Envelope Design Guide

Unified Facilities Criteria

Unified Facilities Guide Specifications

Federal Green Construction Guide for Specifiers

Federal High Performance and Sustainable Buildings

X1.10 United States General Services Administration

GSA Public Buildings Service, The Building Commissioning Guide (2005)

X1.11 United States Department of Veterans Affairs

Whole Building Commissioning Process Manual (2010)

X1.12 California Commissioning Collaborative

California Commissioning Guide: New Buildings (2006)

X1.13 Construction Specifications Institute

Manual of Practice

MasterFormat

UNIFORMAT II

X1.14 National Environmental Balancing Bureau

Procedural Standards for Building Systems Commissioning

Design Phase Commissioning Handbook

X1.15 National Association of State Facilities Administrators

Building Commissioning Recommended Guidelines

X1.16 Portland Energy Conservation, Inc.

New Construction Commissioning Handbook for Facility Managers

Model Commissioning Plan and Guide Commissioning Specifications