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NIBS Guideline 3-2012

Building Enclosure Commissioning Process BECx

This Guideline is for Use with ASHRAE Guideline 0-2005:
The Commissioning Process

An Authoritative Source of Innovative Solutions for the Built Environment

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Joseph Deringer	
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Earle Kennett	VP, NIBS
Stephanie Stubbs	Staff, NIBS

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Building Enclosure Commissioning (BECx) Process

EXECUTIVE SUMMARY

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

GL03 describes a process that provides the flexibility for an owner to incorporate building enclosure commissioning into their project. The Building Enclosure Commissioning (BECx) process is utilized to validate that the performance of materials, components, assemblies, systems and design achieve the objectives and requirements of the owner as outlined in the contract documents. The most effective Commissioning Process ideally begins at project inception (during the Pre-Design Phase) and continues for the life of the facility (through the Occupancy and Operations Phase).

Direction for the commissioning team is provided by the Owners Project Requirements (OPR) at the inception of a project and the proper transfer of this information from one party to the next throughout the life of the building. Due to the integration and connectivity of facility systems, a performance deficiency in one system can result in less than optimal performance in other systems. For optimal performance the building's commissioning team, in the various systems to be commissioned, should include cross disciplinary understanding of related systems with a thorough technical knowledge of their specific area of responsibility. The commissioning team is assembled at the Pre-Design phase and can adapt to the changing nature of the project design and construction phases.

Pre-Design is the preparatory phase of the project delivery process. The owner's initial concepts and desires are documented in the Owner's Project Requirements (OPR). A preliminary outline of the Building Enclosure Commissioning Plan is created to establish the commissioning team, the preliminary scope and the budgets for the various phases of the project.

During the design phase, the BECx process includes the technical review of the design documents and coordination of the building enclosure requirements among the BECx team members. Throughout this phase, the objectives of the OPR are further defined to reflect the owner's decisions and changes. A project specific building enclosure commissioning specification is developed for inclusion in the project manual.

During the construction phase the contractor, specialty subcontractors and the testing agents are engaged in the commissioning process. Specific to each project delivery method, the BECx process incorporates tasks throughout the construction phase, including a preconstruction meeting, review and comment on building enclosure technical submittals and shop drawings. Also participating in laboratory and/or site mock-ups, development of project specific checklists, milestone construction observation site visits and performance testing to validate the installed work complies with the construction documents and the OPR.

The occupancy phase of the BECx process includes training of the owner in operation and maintenance of the building enclosure and inter-related systems. A review of the performance of the building enclosure materials, components and assemblies is recommended prior to the conclusion of the initial warranty period.

This guideline is most appropriate for new construction.

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Building Enclosure Commissioning (BECx) Process

FOREWORD

Building Enclosures have grown more and more complex and typically less and less forgiving for energy performance, occupant satisfaction, durability and operational cost replacement needs etc. This Guideline provides recommendations for navigating the enclosure commissioning process from its necessary inclusion in project planning to its continued emphasis throughout the life of a building. The Guideline is intended to be useable by all owners for all building types. More complex buildings with a lower tolerance for risk derived from poor performance during occupancy will likely increase the involvement of the Building Enclosure Specialist throughout the project delivery process.

The Building Enclosure Commissioning (BECx) process is utilized to validate that the design and performance of materials, components, assemblies and systems achieve the objectives and requirements of the owner. The BECx process achieves this through experience, expertise, modeling, observation, testing, documenting and verifying materials, components, assemblies and systems to validate that both their use and installation meet the owner's requirements. The process uses performance oriented practices and procedures to verify that the project is achieving the Owner's Project Requirements (OPR) throughout the delivery of the project.

Guideline 3 is based on the premise that the owner has hired a competent team that is trusted to design, evaluate and construct a building to meet the project requirements. This guideline describes a collaborative team approach to design, document, deliver and validate, per the OPR, incorporating the expertise and knowledge of a Building Enclosure Specialist (BES) to the benefit of the project.

The BECx process begins during the Pre-Design Phase and continues for the life of the facility through the Occupancy and Operations Phase. The process includes specific tasks to be performed during each project phase in order to verify that the design, construction, operational maintenance and training meet the OPR.

The Commissioning Process is outlined in *ASHRAE Guideline 0: The Commissioning Process.* This NIBS Guideline 3, Building Enclosure Commissioning Process provides a specific process related to the building enclosure. It is recommended that the reader understand and comprehend the base process provided in Guideline 0.

The Commissioning Process should not infringe upon the authority or responsibility of the project's designers or contractors. While the CxA can identify areas of concern, relative to the owner's project requirements, to be discussed with the owner and their team, it is the owner who determines the course of action by the team. It is recommended that the CxA be engaged in predesign to define the scope of the commissioning so that the owner's agreements with the project team clearly define the commissioning tasks that will be performed during the design phases of the project. The commissioning tasks and obligations between the Owner's Design Professionals or Contractors contained in contract forms or project-specific contracts provide the agreement that establishes the foundation for the commissioning process. It is intended to aid these professionals involved in providing an Owner with a facility that meets their expectations and requirements.

Building Enclosure Commissioning (BECx) provides a framework for the management of the design and construction processes to facilitate the successful performance of the building enclosure. It is recommended that, when feasible, the owner engage the BES directly. Otherwise, the BES may be employed as a member of the design and construction team to assist in defining and achieving the goals identified in the OPR.

Reading and Using NIBS Guideline 3-2012

This guideline considers the performance objectives required by an Owner for the building enclosure, including the control of moisture, condensation, heat flow, air flow, water vapor flow, noise, fire, vibrations, energy migration, light, infrared radiation, ultraviolet radiation, structural performance, durability, resiliency, security, reliability, aesthetics, value, constructability, maintainability, and sustainability. The commissioning objectives for a building's enclosure vary by the type of Owner, occupancy, use, size and the project requirements, which may include other requirements across these variables.

It is noted that GL03 is not a one-size-fits-all "how to" document on avoiding poorly performing building enclosures. The annexes to this guideline provide examples of approaches and solutions to a range of specific circumstances during design, construction, testing and O&M.

Approach

Direction for the commissioning team is provided by assembling the documentation of the Owners Project Requirements (OPR) at the inception of a project and the proper transfer of this information from one party to the next throughout the building delivery process. The Commissioning Process has been structured to coincide with the phases of a generic project with Pre-Design, Design, Construction, Occupancy and Operations phases. If circumstances require owners to adopt the commissioning process later in the Design or Construction Phase of a project, such later implementation must capture the information that would have been developed had the Commissioning Process begun at project inception. Beginning the commissioning process at project inception will maximize benefits and minimize the cost.

Due to the integration and connectivity of building enclosure systems, a performance deficiency in one system can result in less than optimal performance in other systems. Although Guideline 3 focuses on building enclosure systems, a successful whole building commissioning process will carefully document and validate interfaces and possible interferences between interdependent building systems. Even if the building enclosure is the singular focus of this process, coordination among disciplines is essential for success.

1 PURPOSE

1.1 The purpose of this guideline is to describe the specific application of the Building Enclosure Commissioning process described generically in ASHRAE Guideline 0-2005.

2 SCOPE

2.1 **Extent:** The procedures, methods and documentation requirements in this guideline describe the application of the commissioning process to building enclosure systems for each building delivery phase from pre-design through owner occupancy and operation.

2.2 **Primary Focus:** The procedures, methods and documentation requirements apply to new construction and to on-going commissioning process activities or requirements of buildings and facilities, or portions thereof. The Building Enclosure Commissioning Authority (BECxA) must be experienced and knowledgeable of the relevant commissioning process, possess a basic comprehension of the building enclosure systems utilized on the project, the performance criteria and the applicable standards and tests to successfully implement this process.

3 DEFINITIONS

3.1 **General:** The following definitions, abbreviations and acronyms are specific to the implementation of the commissioning process to building enclosure systems. These definitions are applicable to all sections of this guideline. Terms that are not defined have their ordinarily accepted meanings within the context in which they are used.

3.2 **Definitions:**

Also see Definitions in *ASHRAE Guideline 0-2005*

Basis of Design (BOD): A document that bridges the objectives conveyed in the Owner's Project Requirements (OPR) and the contract documents (construction drawings and project specifications). It records through narrative the technical concepts, performance, assumptions, decisions and product selections that fulfill the requirements of the OPR and authorities having jurisdiction.

Beneficial Use: When the project, or a portion of the project, is so nearly complete that the owner may use the project for its intended purpose. (See also "Substantial Completion".)

Building Enclosure: The building enclosure includes systems separating one defined environment from another, including walls, fenestration, roofing and roof openings, floors and or ceilings, below grade perimeter walls, crawlspaces and attics from the interior, slabs-on-grade and below grade perimeter walls and interior walls and floor/ceiling assemblies separating interior zones with differing performance criteria.

Building Enclosure Commissioning (BECx): The process by which the design and constructed performance of building enclosure materials, components assemblies and systems are validated to meet defined objectives and requirements of the project, as established by the Owner.

Building Enclosure Commissioning Authority (BECxA): Entity who is designated by the team to formally document the project-specific Building Enclosure Commissioning. This entity should be trained, experienced and knowledgeable in the process of building enclosure commissioning and possess basic architectural and building science knowledge of the design, performance, systems and construction related to the building enclosure. The BECxA role may be accomplished by the BES, CxA or an additional member to the team.

Building Enclosure Specialist (BES): This person or party is deemed an "expert" in the building enclosure systems anticipated to be used on the proposed building and possesses the experience and technical qualifications to design, critique, validate and support the team in the project development and construction validation.

Building Enclosure Commissioning Team : This group is comprised of the Owner, Architect, Engineer, design sub-consultants, Building Enclosure Specialist, Construction Manager, General Contractor, subcontractors, manufacturers, the overall CxA and/or BECxA.

Commissioning Authority (CxA): An entity identified by the Owner who leads, plans, schedules, and coordinates the commissioning team to implement the commissioning process. (Source: ASHRAE Guideline 0-2005)

Commissioning Plan: A document that outlines the organization, schedule, allocation of resources, responsibilities and documentation requirements of the BECx process.

Pre-Design Phase: Pre-Design is a preparatory phase of the project delivery process in which the Owner's Project Requirements are developed and the BECx scope is outlined. See Part 4 of this Guideline.

Design Phase: During the Design Phase of the project delivery process, a design that satisfies the Owner's Project Requirements is developed and translated into Construction Contract Documentation. See Part 5 of this Guideline.

Design Sub-Phases: The design phase is typically broken into three sub-phases, with each being about one third of the total design phase time. These sub-phases have a variety of names but for this document the following terms will be used. Schematic Design, Design Development and Construction Documentation.

> ***Schematic Design:*** (Also referred to as "35% Design.") A phase of building design that produces documents that establish the conceptual design of a project, illustrating the scale and relationship of the Project components, including preliminary selections of major building systems and construction materials.
>
> ***Design Development:*** (Also referred to as "65% Design"). A phase of building design that produces documents that illustrate and describe the refinement of the design of a Project, establishing the scope, relationships, forms, size and appearance of the Project. Major materials and systems are identified including interface details and establishing their quality levels.
>
> ***Construction Contract Documentation or Construction Documentation:*** (Also referred to as "100% Design.") A phase of building design that produces documents that (1) set forth in detail the requirements for the construction of a Project and (2) establish in detail the enclosure performance requirements and the quality of materials and

systems required for the Project. Final Construction Documents are prepared as required to solicit, procure and construct the project and include drawings, specifications, contract forms and conditions, bidding requirements and resource documents. (See also Definitions in Guideline 0.)

Construction Phase: The process of constructing the building to meet the criteria established during the Design Phases and where the building performance as outlined in the Construction Documents is validated through observations and testing.

Completion:

Final Completion: The date when the contractor has completed the contract requirements, the A/E has inspected to determine completion, the owner has made final payment to the contractor and the contractor has accepted final payment. (See also "Substantial Completion").

Substantial Completion: The date established by the A/E when the project, or a portion of the project, is so nearly complete that the owner may use the project for its intended purpose. (See also "Beneficial Use" and "Final Completion").

Guideline: A document written in informative language that provides state-of-the-art design or best practice guidance. Guidelines provide information on system selection, design approaches, practices and goals as well as setting desirable and achievable performance levels. Guidelines may address issues of concern such as startup and commissioning, operation and maintenance and assurance that the goals of the associated standard (if any) are achieved. (Source: ASHRAE 2010 Project Committee Manual of Practice (PC MOP)

Non-Conformance Process: The process for identifying, documenting, evaluating and preventing the inadvertent use or installation of non-conforming items of work.

Construction materials and systems that are found not to be in compliance with the approved project requirements, specifications, drawings, codes or standards and which render the quality of the materials or systems unacceptable or indeterminate requires the generation of a Non-Conformance Report (NCR).

Non-Conformances typically include:
- Physical defects in materials and equipment
- Failures of required tests
- Incorrect or inadequate documentation
- Departures from approved work processes, inspection or testing procedures

Owner's Project Requirements (OPR): A written document that details the goals, concepts, and criteria that are determined by the Owner to be important to the success of the project. The portion of the OPR that relates to the Building Enclosure is considered to be a "living document" for the BECx process and outlines the objectives upon which the Pre-Design, Design and Construction phases are evaluated. (Also see Definitions in Guideline 0)

Peer Review: An objective technical review as part of the BECx process, conducted by a Building Enclosure Specialist, of the design documents, submittals or shop drawings to evaluate the proposed building enclosure systems, details, objectives and performance criteria for compliance to the OPR. The intent is to enhance the quality, reliability and durability of the design.

Independent Peer Review: A peer review conducted by a Building Enclosure Specialist who has no relationship to any firm providing services to the project or known or potential conflict of interests.

Project: The project is the process of planning, design, documentation, contracting, construction and management of a facility. The complete project is a facility, which is a constructed entity or space designed to perform a certain function.

Standard: A document that defines a process for rating purposes, properties, processes, dimensions, materials, relationships, procedures, concepts or nomenclature. Adherence to due process in its development and achievement of consensus are conditions of approval.

Rating standard: A standard that sets forth a method of interpreting the results of tests of individual units, at specified conditions, in relation to a product manufactured in quantity. (Also see **testing standard**.)

Testing standard: A standard setting forth methods for measuring capacity, durability, performance or other characteristics of a specific material, component or system, together with a specification of instrumentation, procedure and calculations. (Also see **rating standard**.)

3.3 Abbreviations and Acronyms

A/E: Architect/Engineer

BECx: Building Enclosure Commissioning

BECxA: Building Enclosure Commissioning Authority

BES: Building Enclosure Specialist

BOD: Basis of Design

Cx: Commissioning.

CxA: Commissioning Authority

GL03: NIBS Guideline 3 for Commissioning of the Building Enclosure

GL03-2006: NIBS Guideline 3-2006 – First version of GL03.

GL03-2012: NIBS Guideline 3-2012 – Second version of GL03

MC MOP: ASHRAE 2010 Project Committee Manual of Practice

OPR: Owner’s Project Requirements

QA: Quality Assurance

QC: Quality Control

Design Phases:

SD: Schematic Design Phase (or 35% design phase)

DD: Design Development Phase (or 65% design phase)

CD: Construction Documents Phase (or 100% design phase)

4 PRE-DESIGN PHASE

4.1 Introduction

4.1.1 Pre-Design is a preparatory phase of the project delivery process in which the Owner’s Project Requirements (OPR) are established and general information about the overall project is gathered, including:

a. Building Enclosure requirements (e.g. materials, durability, energy efficiency and sustainability goals, life cycle of the building and facility interior conditions)
b. Community context (e.g. Codes, regulations, standards, guidelines.)
c. Site information and climate conditions
d. Owner desired spaces that would occur in proximity to the exterior wall, subsequently having a direct relationship to the performance of the building enclosure
e. Occupant comfort requirements
f. Owner’s Training requirements to facilitate maintenance and successful operation of the building enclosure.
g. Documentation requirements
h. Other owner requirements, such as insurance company requirements, facility guidelines or preferred systems/manufacturers.

The OPR developed during Pre-Design should be recognized as a starting point for subsequent design phases. The OPR will continue to evolve during the design phases in order to balance the functional, performance and budgetary criteria of the project.

4.1.2 Objectives:

a. Document the Owner’s Project Requirements (OPR)
b. Identify a scope and budget for the Commissioning Process
c. Communicate commissioning requirements of the design team for inclusion in agreements between owner and design team
d. Initiate development of the Commissioning Plan
e. Provide Pre-Design Phase BECx Progress Summary Report

4.2 Kickoff Meeting

4.2.1 Commissioning activities in the Pre-Design phase begin with a Kickoff Meeting. The agenda of this meeting includes identification of project objectives and discussion of the project’s commissioning process. The agenda may include:

a. An introduction to the BECx process, including the various tasks and objectives of each phase.

b. The project delivery method and the extent to which the various building systems will be commissioned. Coordination with other systems to be commissioned should be addressed.
c. Design objectives including the Owner's approach to energy usage, facility life cycle requirements and code requirements.

4.2.2 Commissioning Team Members and Responsibilities.

4.2.2.1 The project team dedicated to the implementation of the commissioning process is established by the Owner to oversee and accomplish the tasks outlined by this Guideline. A Commissioning Authority (CxA) is designated by the Owner to supervise the overall commissioning process. The Building Enclosure Commissioning Authority (BECxA) may be designated by the team for Building Enclosure Commissioning responsibilities. The BECx team includes a Building Enclosure Specialist (BES) to provide technical expertise and participate in the commissioning process as outlined in this Guideline. The BECx team members aid in the development of the OPR.

4.2.2.2 Annex F lists the roles and responsibilities of the essential members of the Commissioning Team. The project's commissioning team may likely change throughout the project duration to adapt to the shifting emphasis of the projects' demands, however representation of the BES should remain consistent.

4.2.2.3 Responsibilities for the building enclosure commissioning team include:

a. Facilitate the development of the building enclosure objectives into the OPR.
b. Establish the protocols for documentation, the format for the building enclosure maintenance and inspection manual and BECx Final Report.
c. Establish BECx plan, scope and budget.
d. Verify the roles and responsibilities for each member of the team. Understand the nature of the commissioning tasks, and how they may impact each independent team member or trades' scope of work.
e. Identify building enclosure commissioning tasks in the project schedule.

4.3 Owner's Project Requirements (OPR) Document

4.3.1 This document provides the basic requirements from which design, construction, acceptance and maintenance decisions are made. Information is included to assist the project team plan, design, construct and maintain a durable building enclosure. The BES facilitates workshops to obtain building enclosure objectives from the Owner's team as appropriate for the OPR. The OPR evolves throughout the project, and is used for benchmarking performance metrics and decision making during all phases of the project.

4.3.2 The pre-design phase OPR document may include:

4.3.2.1 Project definition including function, project schedule and budget

4.3.2.2 A building enclosure vision, including any Owner directives, restrictions or limitations, durability expectations and building enclosure life expectancy. The Owner may wish to achieve building enclosure performance objectives / requirements beyond basic code, and should consider items such as (but not limited to); increased energy efficiency, environmental and sustainability goals, community requirements, adaptation for future expansion, integration of systems, indoor environmental requirements, acoustics, security or communications.

4.3.2.3 User requirements, building safety and maintenance access requirements, occupant schedules, training of facility engineering, and “lessons learned” from previous projects.

4.3.2.4 Substantial development of the design and function of the building enclosure is developed in the Design Phase by the Architect and the Basis of Design document.

4.4 Identify the Scope and Budget for the Commissioning Process

The preliminary estimates of Cx scope and budget, developed early on during the Pre-Design Phase, are important tools that permit the Owner to balance objectives for the building, with costs of achieving those desired levels of performance. Identifying this balance between desired level of commissioning to validate performance for the enclosure and the costs to achieve at this early point in the process will provide a basis for subsequent decision making by the building delivery team. Also, the tradeoffs between performance and cost will likely be revisited and refined numerous times during the subsequent phases of design, construction and occupancy, using this early set of estimates as a starting point.

4.4.1 The BECx budget should include preliminary estimates of the costs to accomplish the Commissioning Process activities including but not limited to:

4.4.1.1 The activities of the commissioning team during the building design, construction and occupancy phases

4.4.1.2 Design peer review and modeling validation and/or review to confirm conformance to the OPR.

4.4.1.3 Mock-up and/or field performance testing of building enclosure materials, components, systems and assemblies during initial installation, and at various stages throughout construction. (If a conceptual building enclosure design is available),

4.5 Commissioning Plan

The Commissioning Plan identifies the processes and procedures necessary to achieve the Construction Documents. The plan should respond to the individual project specific requirements, geometry, environment, interior conditions, function and owner requirements, the Owner’s risk management strategy and overall complexity of the building enclosure design and performance requirements. The BECx plan should define:

4.5.1 The roles and responsibilities of the project team members performing BECx, including all tasks that are to comprise the process. These tasks should be project specific and include detailed references to the Construction Documents. The BECx plan should maintain focus on achieving these requirements.

4.5.2 The BECx plan, which is to be reviewed and updated throughout the duration of the project.

4.5.3 The communication protocols and methods for distribution of information among the team. Electronic based software are often utilized; however the applicability for building enclosure commissioning tasks should be verified prior to engaging in this form of communication. Critical capabilities of the methods of communication include tracking of communication, links to images and construction documents, timeliness, and tracking of building enclosure verification related issues.

4.5.4 The communication processes for reviewing designs, non-conformances, resolving issues, and sharing information and documentation among the Commissioning Team members. Contact information should be included for the Commissioning Team members and other key project participants.

4.5.5 The format of the Construction Checklists, is to be reviewed by BECx team for implementation.

4.5.6 The format of the Final Commissioning Report, including the close-out documents, as described in section 7.1.1.

4.5.7 Facility Maintenance personnel training requirements, as established by the Owner.

4.5.8 The format of the issues / non-conformance log, including detailed descriptions of the design, installation or performance issues that are at variance with the OPR and/or the Contract Documents.

4.5.9 The issues log procedures, identifying how issues should be tracked and resolved in a timely manner. Issues should be tracked via a unique numbering system including the observer of the issue, responsible party and the following:

4.5.9.1 Description of the issue and system impacted, date of identification and required correction/response, test (as applicable), location of issue, reference to specific detail or specification section, recommendations and/or corrective action.

4.5.9.2 Resolution of issue including, date of correction, description of correction including assessment of the issue and repair technique/process and tests performed to validate repair, any accepted deviations from the contract document or OPR, Party resolving the issue, communication between parties and documented acceptance by the Owner/ Architect of the issue's resolution.

4.6 Prepare Commissioning Process Progress Report

A summary report outlining the tasks of the Pre-Design Phase of the commissioning process should document the process and work product developed during this phase.

The progress report should be included in the final commissioning report.

5 DESIGN PHASE

Introduction

The design phase is comprised of tasks that verify the Owner's Project Requirements are comprehensively outlined, detailed and specified in the Contract Documents (CD's). Design reviews are performed and documented by the Building Enclosure Specialist, and team meetings are held to review and discuss building enclosure systems and their performance for compliance with the OPR. The BECx plan is further refined and the BECx project specific specification is included in the Project Manual.

5.1 Schematic Design (SD)

5.1.1 In this preliminary phase, emphasis should be on the impact on budget and schedule required for commissioning of various enclosure options. Each building enclosure system has specific tests and tools available for qualitative and/or quantitative analysis of performance, with varying degrees of certainty.

5.1.2 SD BECx Meeting

5.1.2.1 If a substantial gap in time has occurred from the Pre-Design phase meetings, Schematic Design should begin with the Project Team participating in a meeting to address objectives for commissioning of the building enclosure.

5.1.3 SD Basis of Design review

5.1.3.1 Review SD BOD document to check that systems presented provide an acceptable design solution to fulfill the OPR requirements, both for enclosure requirements and integrating the enclosure with other building systems. The BOD should include narrative descriptions of building exterior enclosure systems (e.g., roof, exterior walls, floors, windows, skylights, atria, thermal mass, etc.).

5.1.4 SD Technical review

5.1.4.1 Perform a technical peer review of the building enclosure, including the alternative schemes for appropriateness and impact on the OPR at intervals during SD appropriate for the complexity of the project.

5.1.4.2 Review the Schematic Design phase, rough concepts of the building, and materials in comparison to the OPR. The comparison should be undertaken for the building enclosure as well as criteria for other systems and other project criteria including the functional program, budget, aesthetics and performance. Analysis of conceptual solutions should include impact of inter-dependent systems (refer to Annex R).

5.1.5 Evaluate and update the building enclosure criteria in the OPR.

5.1.5.1 Throughout the design phase review and compare alternatives developed by the A/E appropriate for the development of the project.

5.1.5.2 Update the OPR as the criteria is developed and finalized. The OPR should be updated and expanded with explanations and changes recorded to document decisions.

5.1.6 SD Commissioning Plan

5.1.6.1 The building enclosure Commissioning Plan helps the owner understand the requirements and risks associated with each enclosure system in delivering the anticipated level of performance and the cost and schedule impact of the Commissioning activities.

5.1.6.2 Update and expand the preliminary building enclosure Commissioning Plan outlined in Pre-Design in parallel with the examination of alternative schematic concepts for building enclosure systems, the selection of preferred systems from the alternatives and the design of the selected systems. Coordinate the plan with the Owner's Project Requirements (OPR) and Basis of Design (BOD).

5.1.7 BECx SD report

5.1.7.1 Perform a review of objectives at end of the Schematic Design Phase. BES should conduct a Project Team review meeting to address whether the objectives for Schematic Design phase have been met. Unresolved issues should be documented, and the resulting issues log becomes a resource for beginning the subsequent design phase.

5.2 Design Development (DD)

5.2.1 DD Phase Project Team Commissioning is a crucial phase in the design/commissioning process, as the concept of the building is well enough established to allow resolution of the building enclosure design against highly defined and precise owners criteria. In this phase more detailed drawings, large-scale wall sections, elevations and details and preliminary specifications for the building enclosure systems are developed in support of the schematic design concept and BOD. The OPR is updated to reflect ongoing decisions. The Design Development Documents are verified against the OPR.

5.2.2 DD BECx Meeting

5.2.2.1 If a substantial gap in time has occurred since the Schematic-Design phase meetings, Design Development should begin with the Project Team participating in a meeting to address objectives for commissioning of the building enclosure.

5.2.2.2 Early in DD, comparisons of various options for the building enclosure systems should be conducted by the design professional and reviewed by the BES. For each surface, variations between the layering of the assembly should be considered including balanced comparisons of cost, performance and aesthetics. The systems are continually evaluated by the BES in comparison to the OPR. At completion of DD, all surfaces of the building enclosure, including below grade, should be identified as a complete assembly with all layers identified. The air, water, thermal and vapor control layers as well as means to meet all other criteria included in the OPR should be identified.

5.2.2.3 A determination and hierarchical analysis of the design performance and aesthetic parameters should be compiled to balance objectives in the OPR and provide maximum value to the owner. Methodologies for calculating and verifying the design performance values should be determined. An analysis of the impact to the durability, resilience and value of the systems by adjusting the design parameters up or down should be communicated to the owner. The cost and possible return on investment for methodologies to more precisely predict or model actual design response needs should be considered, scheduled and included in the OPR. The BES should to review this work by the A/E.

5.2.3 DD BOD Review

5.2.3.1 The BOD outlined during the Schematic Design Phase is updated and substantially completed during DD, requiring only minor updating in subsequent phases. Perform a review of the BOD to verify it includes the following:

5.2.3.2 The architect should assemble and the BES should review a description of each system option considered, such as type of building enclosure system, sub-systems, materials and components and the interaction of the building exterior enclosure system with the heating, cooling, mechanical and natural ventilation, daylighting, lighting, building interior and other systems. The description should explain how the designer intends to meet the building enclosure-related Owner’s Project Requirements.

5.2.3.3 Review the BOD to verify that solutions presented fulfill the OPR requirements, both for enclosure requirements and integrating the enclosure with other building systems.

5.2.4 DD Technical review

5.2.4.1 Perform a comprehensive technical peer review, including the development of detailing appropriate to achieve the OPR, at intervals during DD appropriate for the complexity of the project.

5.2.4.2 BES should attend regularly scheduled meetings, conference calls / web based conferences with the Project Team during Design Development at milestone intervals appropriate for the complexity of the project and the expertise of the project team.

5.2.4.3 Review alternative building enclosure systems and materials suggested by the team (A/E, CM, GC, subcontractors) at the beginning of DD. BES should provide advice on selection and alternates.

5.2.4.4 Review the design development documents for comparison of building enclosure assemblies and details, required testing and typical details for interfacing continuity. Details to be reviewed should include, but are not limited to: Typical details for roof to wall, foundation-to-wall, fenestration, wall to floor, wall to column, wall to floor, penetrations and other features that are common or highly repeated for the various enclosure assembly layering options.

5.2.4.5 Review the initial development of typical plans and details for interface of the various enclosure systems. Review both constructability and the design continuity for air, water, thermal and vapor control layer interfacing details are to be evaluated. The DD documents should clearly identify the extent of each control layer. At each interface between systems, i.e. window to wall, wall to foundation, wall to roof, verify continuity and compatibility of control layers and performance. The design review report should advise the project team on technical matters; provide recommendations for the development of details, systems and assemblies; and review documents for completion and coordination.

5.2.4.6 Review the DD specifications for the BECx process. The specification should outline the roles and responsibilities of the commissioning team during construction; testing, occupancy and operations commissioning responsibilities of the commissioning team; and documentation requirements.

5.2.4.7 Review numerical thermal analysis provided by the A/E or sub consultants of various systems to determine actual averaged U-values for each opaque enclosure system and actual averaged U-values, Solar Heat

Gain Coefficients, and Visible Transmittances for the fenestration assemblies.

5.2.4.8 Coordinate with design team specialty disciplines and provide input regarding other specialized engineering considerations such as long-span structures, special lightweight structures, structural glass, blast loading, etc.

5.2.4.9 Review and provide advice on laboratory and field mock-ups, testing and inspection procedures.

5.2.4.10 Review the Outline or Draft DD specifications for preferred materials and systems, technical competency coordination with details and inclusion of commissioning activities.

5.2.4.11 Review documents for integration and coordination with related systems including structure, HVAC, daylighting, etc.

5.2.4.12 Review the ability of each enclosure system identified for the capability of that system to satisfy the OPR and for the appropriateness of use of that system within the overall design.

5.2.4.13 Review the final DD plans and specifications before proceeding into the Construction Documents phase.

5.2.4.14 Conduct a Project Team review meeting to address whether the objectives for Design Development phase have been met. Outstanding issues should be documented, and the resulting issues list becomes a resource for beginning the Construction Documentation phase.

5.2.5 Evaluate and update the OPR

5.2.5.1 During Design Development, the OPR should be updated to include specific quantitative performance values based on industry established standards for every necessary performance characteristic. The criteria must be complete and specific so that the DD level design solutions can be verified for performance requirements of the OPR. Refer to Annex J for a complete listing of criteria for the OPR.

5.2.6 DD Commissioning Plan

5.2.6.1 At the end of Design Development phase, the Building Enclosure Commissioning Plan should be substantially completed. During DD the extent of laboratory mock-ups with associated testing protocols, the number, size and disposition of field mock-ups with associated testing protocols, independent inspection and special inspections should be determined. Special requirements for the CM's /Contractor's quality programs should be written into the specifications. The Commissioning Plan should be coordinated against the Owner's Project Requirements (OPR) and customized to the building design. The BECx Plan should include:

5.2.6.1.1 A list of systems to be documented and tested including frequency of testing.
5.2.6.1.2 Outline of inspection protocols and testing procedures with acceptance requirements.
5.2.6.1.3 A preliminary Schedule of building enclosure related Commissioning Process activities for the Construction Phase and the Occupancy and Operations Phase. The schedule should identify critical times for witnessing testing activities, building enclosure systems and activities relative to substantial completion/project closeout.

5.2.7 DD BECx Report

5.2.7.1 Perform an objectives review at end of the Design Development Phase. Conduct a Project Team review meeting to address whether the objectives for Design Development phase have been met. Unresolved DD issues should be documented, and the resulting issues log becomes a resource for beginning the Construction Document phase.

5.3 Construction Documents (CD)

5.3.1 During CDs, the building enclosure systems and typical details selected in Design Development are fully developed for all of the specific interfacing conditions required for the project. In this phase, more details and sections are added along with comprehensive schedules. The Construction Documents become the delivery method of the OPR and are completed to a level of detail and specificity to allow for procurement and construction of a building that meets the OPR.

5.3.2 The CDs are evaluated against the OPR. Drawings from the DD phase are supplemented with additional information. A final specification for the commissioning of the building enclosure systems is produced to match the BOD including performance criteria drawn from the BOD. Commissioning activities required of the Contractor are included in the specification. The OPR and BOD are updated to reflect final changes necessitated by completion of the CDs. The generic process is provided in Annex B.

5.3.3 CD Technical review

5.3.3.1 Review the OPR and the DD Peer Review notes for any DD phase activities which may still be open.

5.3.3.2 Provide advice to the project team on technical matters, recommendations for the development of details, systems and assemblies, and review the CD documents for completion and coordination.

5.3.3.3 Meet with the Project Team periodically during Construction Document phase at intervals appropriate for the complexity of the project and the expertise of the project team.

5.3.3.4 Provide recommendation(s) for the development of additional details and drawings. Review entire set of CD documents for completeness and coordination.

5.3.3.5 Review CD details for continuity, performance, constructability and value. Review details for interface of the various enclosure systems.

5.3.3.6 Provide advice regarding heat/air/moisture performance of details. Back check and provide review of numerical thermal analysis by the A/E team, if necessary.

5.3.3.7 Provide additional input regarding other specialized engineering considerations such as long-span structures, special lightweight structures, structural glass, blast loading, etc. Review documents for integration and coordination with related systems including structure, HVAC, day lighting, etc.

5.3.3.8 Review and provide advice on mock-ups, testing and inspection procedures.

5.3.3.9 Review the ability of each enclosure system identified for the capability of that system to satisfy the OPR and for the appropriateness of use of that system within the overall design

5.3.3.10 Review specifications for materials and systems for sufficiency and coordination with the CDs. Review specifications for inclusion of Commissioning Process requirements, including submittal requirements, training requirements, testing requirements, inspection requirements, mock-ups, performance requirements, CM's/ contractors quality assurance requirements, etc.

5.3.4 Evaluate and update the OPR

5.3.4.1 The OPR produced in DD phase is updated for changes and final adjustments that occur during the CD phase. Unless the Construction Documents are substantially changed, the OPR should not require substantive changes during CDs. Information regarding final material selections is updated and checked for co-ordination with other building enclosure materials and systems.

5.3.4.2 Review the ability of each enclosure system identified for the capability of that system to satisfy the OPR and for the appropriateness of use of that system within the overall design.

5.3.4.3 Review OPR at end of CD Phase. Review the CD phase activities to verify fulfillment of OPR. Review the Commissioning Activities going forward into procurement and construction.

5.3.5 CD Commissioning Plan

5.3.5.1 The Building Enclosure Commissioning Plan prepared in DD phase is updated and finalized. Revisions to the Commissioning plan must be coordinated with the commissioning activities included in the final specifications issued at the end of CDs.

5.3.5.2 The Schedule of building enclosure Commissioning activities is updated for the Construction Phase and the Occupancy and Operations Phase. The schedule should identify critical times for witnessing testing activities, building enclosure systems and activities relative to substantial completion/project closeout.

5.3.5.3 Update the BECx budget for the Construction phase.

5.3.6 CD BECx specification

5.3.6.1 Develop a project building specific building enclosure commissioning specification, outlining the roles and responsibilities of the construction phase commissioning team.

5.3.6.2 Develop a project specific matrix that clearly summarizes the type of testing, who is to perform, when will testing be performed, what is the criteria for acceptance, how is the testing to be documented, who will receive the documentation of these inspections.

5.3.6.3 The Commissioning Process should use random sampling (based upon a known probability distribution of expected values, an assumed statistical distribution or random sampling based upon best judgment) for verification of each building enclosure system, and determined by the values, criteria and expectations defined in the Owner's Project Requirements. In developing the test procedures, special attention must be paid to issues of personnel safety, equipment/assembly protection, access and the site's ability to provide water, electricity, etc., to successfully perform the tests.

5.3.7 Include a Building Enclosure Systems Maintenance Manual, which should be updated to incorporate information generated during the Construction Phase. The Manual should include an overview of all enclosure types and systems. The purpose and general overview of each enclosure type and location installed, in addition to maintenance and inspection schedule should be included in the Manual. The general description section should meet the knowledge needs of the Engineering and Maintenance staff, occupants and owners. In addition, add the following items to the Manual:

5.3.7.1 Maintenance requirements - periodic inspection of the building enclosure

5.3.7.2 Replacement schedule - based upon the service life of the building enclosure system and the individual materials and subcomponents.

5.3.8 Construction Documents Phase BECx report

5.3.8.1 BES should conduct a Project Team review meeting to address whether the objectives of the Design phase have been met in the construction documents. Unresolved issues should be documented and resolved in the OPR and the Construction Documents prior to beginning the project's Construction Phase.

6 CONSTRUCTION PHASE

Introduction The recommended building enclosure commissioning team members during the Construction Phase are to include but are not limited to: Owner, A/E, specialist design sub consultants, CxA, BECxA (as required), BES, Construction Manager, General Contractor, Subcontractors, Manufacturers, Independent Testing Laboratories and others as required by the project.

6.1 The Commissioning Process activities described in this section, which are performed by the members of the Construction-Phase Commissioning Team, are described in ASHRAE Guideline 0. Requirements pertaining to building enclosure may include, but are not limited to:

6.1.1 Review the construction documents. Discuss with the Commissioning Team any concerns or possible need for detail alterations due to sequencing issues or failures during the laboratory mock up, field mock up or other tests performed during the pre-construction phase.

6.1.2 Conduct additional field testing as required if failures occur during the laboratory mock up, field mock up, or the field tests performed during the construction phase. Additional testing may also be needed if substitutions of materials and systems are accepted during the construction submittal phase.

6.1.3 Conduct field review of the aesthetic and performance of mock-up(s). Review of the unique interface conditions with differing materials to verify they meet the design intent and will provide the performance levels and functionality of the building enclosure as specified in the contract documents. Mock-ups construction and testing must be scheduled with float time allowed for the remediation of unforeseen issues by way of iterative repair submittals and field performance testing of the mock up repairs prior to actual construction.

6.1.4 Thoroughly review submittals, including: shop drawing(s), mockups, initial installation, sample constructions, project schedule and sequencing, and all building enclosure components allowing for revisions as necessary to provide the level of performance as specified in the contract documents.

6.1.5 Review the Contractor’s and Subcontractors’ Site-Specific Performance Implementation Plans for the building enclosure, including but not limited to the implementation and use of quality control/ quality assurance processes including but not limited to daily field inspections, first work testing, documentation, weekly audits and the use of project specific installation checklists for each crew.

6.1.6 Develop project specific checklists related to the installation of components and systems that comprise the building enclosure.

6.1.7 Implement an Issues / Non Conformance Log process including discussion of Non Conformances at the Owner/Architect/ Contractor (OAC), project weekly progress and coordination meetings and routine building enclosure commissioning team meetings, development of reports resulting from construction observations, field testing, issues / non conformances, and formal documentation of the resolution for work of Issues / Non Conformance logs.

6.1.8 Conduct construction observation of building enclosure systems, at initial installation of work, milestone observations throughout construction, performance testing and verification of components and systems, interfaces and whole building performance test (if required).

6.2 Construction-Phase Commissioning Process Activities The following activities are to be performed as part of the BECx process, with specific tasks by the Building Enclosure Specialist as outlined below:

6.2.1 Conduct Pre-Construction BECx Kick-off meeting to outline the objectives of the BECx process, as well as the team member roles and responsibilities. Items to discuss include, but are not limited to: submittals, mock up, construction sequencing, constructability, BECx documentation process, field observations, field performance testing activities including repair and re-testing, project schedule, Issues Log and other issues designated by the BES pertaining to the project coordination, validation and construction of the building enclosure.

6.2.2 Coordinate with the Owner's Representative who is participating in the building enclosure commissioning activities.

6.2.3 Perform technical reviews of the Building Enclosure Submittals, assist in the evaluation of substitution requests and provide documentation.

6.2.4 Perform periodic construction observation review of Contractor's efforts to assure and control workmanship, functional installation, and material and assembly performance. Perform construction observations at milestone activities, including but not limited to mock-ups, commencement of new trades, randomly scheduled site review and field testing.

6.2.5 Attend meetings to coordinate and review performance testing with contractors, and contractor's execution plans to address issues. Review contractor implementation of checklists.

6.2.6 Attend regularly scheduled BECx meetings and review/discuss the Building Enclosure schedule and the Issues Log with the CM, GC and Subcontractors.

6.2.7 Observe, coordinate and/or perform and document field performance testing as outlined by the building enclosure commissioning specification and related sections. Interpret test results and recommend additional testing if deemed necessary due to failure or systemic conditions.

6.2.8 Update Owner's Project Requirements:

6.2.8.1 Coordinate the CM, GC, Subcontractor Schedule and Implementation Plans for the Building Enclosure Training Program for the Owners personnel.

6.2.8.2 Update the OPR to reflect modifications to the design accepted by the Owner and Architect-of-Record resulting from the construction phase activities.

6.2.9 Update the Commissioning Plan:

6.2.9.1 Review or coordinate the CM/GC, Subcontractor Schedule and Implementation Plans for the Building Enclosure Training Program for the Owners personnel.

6.2.9.2 Update the BECx Commissioning Plan to reflect modifications resulting from the construction phase activities.

6.2.10 Attend Pre-Construction Sub-Contractor Meetings:

6.2.10.1 During Sub-Contractor pre-construction meetings, familiarize the construction team with the commissioning process and address any special project performance related to the OPR.

6.2.10.2 Attend the pre-construction meetings held for each building enclosure trade /component. During these meetings BES leads discussions of the specific observations, performance tests and documentation to be conducted on the components and assemblies, scheduling and sequencing, review of checklists, review of the Contractor Site Specific Quality Plan, review of Non Conformances/Issues Log / inspections, testing and documentation protocols and finalization of construction checklists.

6.2.11 Verify Submittals: Drawings and specifications should be reviewed for the following:

6.2.11.1 Review the building enclosure shop drawings in direct reference to the contract documents and the OPR, with respect to building enclosure issues that may impact the constructability, function, durability of the individual materials, installation instructions from the manufacturer, maintenance and replacement, including but not limited to:

a. Review the interface conditions, tolerances, sequence of installation, material compatibility.

b. Integrate and coordinate shop drawings for interfacing materials.

6.2.11.2 Review product data for the following:

a. Conformance with the project construction documents and OPR.

b. Compatibility and adhesion to adjacent building enclosure components. Evaluate that the durability meets intended life of building enclosure system or that the product can be removed and replaced as part of scheduled maintenance during the service life of the specific building enclosure.

6.2.11.3 Review Project Schedule for inclusion of BECx activities, including but not limited to:

a. Schedule of submittals

b. Laboratory testing

c. Sample construction
d. Mock up testing,
e. Field performance testing (possible repairs)
f. Inspection by the Jurisdiction Having Authority or Code Authority.

6.2.12 Schedule BECx Process Activities:

6.2.12.1 BECx Team meetings: Hold routine meetings during the building enclosure field construction to discuss performance testing, issues log, and testing schedule with associated documentation.

6.2.12.2 Field Observations: Document installation date, details of the installation, non-conformances / issues.

6.2.13 Review the implementation of the CMs/GCs Site Specific Building Enclosure Performance Verification Program for (the quality control and quality assurance) procedures and compliance with contract documents.

6.2.13.1 The BECx team reviews the project performance Quality Control/Quality Assurance (QC/QA) requirements and Commissioning activities to verify the following objectives are achieved and apply to all building enclosure systems and features that are to be commissioned.

a. Verify field testing, including type, location and frequency as outlined by the specification and associated building enclosure sections in the Project Manual. Protocols to address failures, repeat tests and additional testing as warranted.
b. Implement a project specific plan that includes testing, who is to perform the testing, when testing will occur, criteria for acceptance, how testing will be documented and who will receive the documentation of the testing.
c. Verify the test procedures validate the various systems and assemblies that comprise the building enclosure deliver the intended Owner's Project Requirements.
d. Verify the manufacturers performance testing performed by an independent third party certified laboratory per the Contract Documents. Verify that the testing agency meets requirements of the certifying authority.
e. Confirm all submittals required by the contract documents for each building enclosure system and each sample construction have been submitted and approved.
f. Verify that Contractor and the BECx QC Checklists are utilized and proper documentation implemented throughout the enclosure construction phase by the CM/ GC and their subcontractors.
g. Verify mock up construction in the field to demonstrate workmanship has been completed and the work in place on the building complies

with the manufacturer's installation instructions, design intent and specifications.

If required by the project, verify formal mock-up testing submittal/ mock up performance testing has been completed, Non conformances have been resolved and the tested system(s) are confirmed to be formally approved by the design professional for project installation.

6.2.14 Conduct BECx Team Meetings required to specifically address building enclosure related issues. The meetings may or may not be conducted within a regularly scheduled commissioning meeting. Attendees should include all parties, including the BES and disciplines affected by the subjects under consideration. Agenda of such meetings is to involve:

6.2.14.1 Building enclosure installation and testing, which may require the coordination with HVAC & MEP equipment as well as with additional disciplines such as structural, HVAC, fire protection.

6.2.14.2 Review of performance test procedures and schedule.

6.2.14.3 Review of Issue Logs /non-conformances

6.2.14.4 Review of checklist implementation.

6.2.15 Perform Site Visits.

6.2.15.1 Perform site visits to verify and document compliance with the Contract Documents and the Owner's Project Requirements. Coordination of the scheduling of these building enclosure system visits should involve the contractors, manufacturers, and consultants in relation to the project schedule.

6.2.15.2 Perform site observations to coordinate with specific installation of enclosure details, including field mock-ups, start-up of trades, complex details, field testing and problematic installations.

6.2.15.3 Verify that the building enclosure checklists are utilized daily and monthly summaries generated and submitted to the BECx team, for review. Checklists should note all non conformances with repairs properly documented and signed off by design and construction team members.

6.2.15.4 Document site observations and testing, promptly identifying issues or non-compliance issues on the Issue Log.

6.2.16 Performance mock up and field test execution. Testing is to be conducted in accordance with the specifications, and observed and/or performed by the BES and BECx team.

6.2.16.1 Show locations of the building enclosure field performance tests on project drawings, specifically on exterior elevations and roof / waterproofing plans.

6.2.16.2 Record environmental conditions, e.g. ambient temperature, humidity, time-of-day, solar conditions, wind, rain at time of testing.

6.2.16.3 Document the test results, including re-verification that the test standards and performance criteria adapted by the testing agency prior to and during testing are consistent with the criteria established in the contract documents for the project and appropriate for the building enclosure material, component, system or assembly to be tested. Document whether a test passed or failed, and any remedial action that was completed during the test, and the applicability of said remedial action to similar building enclosure systems or assemblies that may exist at other locations throughout the project. The number of all tests completed is to be noted, together with a list of names and contact information for all witnesses to each test. Provide observation, review and commentary, as appropriate, on:

a. The anticipated long-term durability of all remedial actions taken as a result of non conformance testing.
b. Review the approved submittals made by the parties responsible for non conformances inclusive of the repair submittal for the non conformance and field mock-up of trial repairs
c. Verify that said remedial action for each non conformance has been properly executed on a building-wide basis where applicable.

6.2.17 Submit draft Construction Phase BECx Report for Owner review. Submit the draft report to other Commissioning Team members for review. Incorporate review comments from all BECx team members, including the Owner, into the final construction phase BECx Report.

6.2.18 Verify that the Building Enclosure Systems Manual is updated to incorporate information generated during the Construction Phase. Verify that the Manual includes an overview of all enclosure types and systems. Include in the Manual the purpose and general overview of each enclosure type and location installed, in addition to maintenance and inspection schedule. The general description section should meet the knowledge needs of the Engineering and Maintenance staff, occupants, and owners. The Manual should include, general maintenance requirements, including periodic inspection of the building enclosure, and a replacement schedule, based upon the service life of the building enclosure system and the individual materials and subcomponents.

6.2.19 Verify Updates to the OPR. Review updates to the OPR provided during the construction phase.

6.3 Construction Phase Documentation Requirements: Documentation of the building enclosure to include: Action Item logs (including resolution and unresolved items), testing results and areas where testing was performed, remediation of problems encountered during construction and verification of as-built documents, Final BECx Plan, Final OPR and Building Enclosure Maintenance Manual.

7 OCCUPANCY AND OPERATIONS PHASE

7.1 Introduction. The following information focuses on the Commissioning Process as it applies to the Building Enclosure and is to be performed by the CxA. See also Annex B, Flow Diagram, Occupancy and Operations Phase

7.1.1 Preparing for the submittal of the Substantial Completion Document. Active involvement by the BES at this significant transition from building the facility to using it is essential to successful completion of the Building Enclosure Commissioning Plan. At this phase, the BECxA is to verify the accuracy of the documentation records required by the Commissioning Plan relative to the acceptance of the completed Building Enclosure including:

7.1.1.1 Enclosure Test Records

7.1.1.2 Record Drawings

7.1.1.3 Final Commissioning Report

7.1.1.4 Documentation Review and Verification of Conformance Requirements

7.1.1.5 Building Enclosure Preventative Maintenance Program including cyclical verification of Building Enclosure components with enforcement of warranty provisions.

7.1.1.6 Additional documentation and verification as specified in the OPR.

7.1.1.7 Prepare final version of the OPR

7.1.2 Documentation Requirements for Substantial Completion. Completion of all Owner Project and Agreement Requirements or Documented Amendments. The Commissioning Authority is responsible for verifying full compliance of the following:

7.1.2.1 Verify Owner acceptance to all corrective actions for Building Enclosure systems, components, and controls.

7.1.2.2 Organize corrective action logs and coordinate schedule for completion of record documentation.

7.1.2.3 Organize testing results for Building Enclosure systems and assemblies demonstrating conformance to the levels specified in the OPR.

7.1.2.4 Document Owner acceptance of any non-conforming work or exceptions to the OPR.

7.1.2.5 Create a lifecycle impact statement using a method of analysis whereby non-conforming Building Enclosure conditions are evaluated for projected impact during the expected lifecycle of the Building Enclosure.

7.1.3 Schedule of Services during the Warranty Phase. The BECxA should verify that the Contractor provides the Owner with a project specific schedule of services available following Final Acceptance to completion of the Warranty Period. These may include:

7.1.3.1 Operation and Maintenance training update

7.1.3.2 Verification of Building Enclosure seasonal performance levels to design specifications

7.1.3.3 Building Enclosure Lifecycle verification test results

7.1.3.4 Building Enclosure Post-construction design evaluation

7.1.3.5 Coordinating site visits and verification programs provided by manufacturer's representatives, vendors and sub-contractors.

7.1.3.6 Updating Construction Record Documents

7.1.3.7 Occupancy and Operations Phase Commissioning Process Activities for Building Enclosure Systems

7.1.4 Verification of Commissioning Responsibilities for new work identified in the Commissioning Plan.

7.1.4.1 Building Enclosure sustainability analysis verification.

7.1.4.2 Building Enclosure Warranty enforcement matrix, and end of warranty review.

7.1.4.3 Conformance verification to Standards and Codes references in Construction Documents and Maintenance Manual.

7.1.4.4 Documentation Record that the completed work meets the levels of Quality established in the OPR

7.1.5 Coordinate Building Enclosure Contractor Call-back and Warranty Enforcement.

7.1.5.1 Perform review of building enclosure, prior to end of contractors warranty period.

a. Building Enclosure Warranty Period – 10 month inspection
b. The project warranty for installation has a typical duration of 12 months.
c. The Warranty Period walk through inspection for the Building Enclosure should be scheduled at 10 months and should include representatives from the Owner, A/E, Facilities Management, CM, GC, subcontractors and manufacturers.

7.2 Final Project Commissioning Report.

7.2.1 Provide a summary of all commissioning activities that occurred as stated in Guideline 0, including project specific Maintenance Manual and Inspection Schedule for use by Owner maintenance personnel.

Annex B: Flow Diagram of Building Development and Commissioning Processes

Commentary

This annex is intended to provide a detailed description of the commissioning (Cx) process and how it relates to the overall building development process. While the intent has been to describe the commissioning process for the building exterior enclosure, the flow diagrams contained on the following pages are probably sufficiently general to be used to describe commissioning and building development processes for all major building systems.

This annex is a major expansion of a less detailed flow diagram that is listed in Appendix B of ASHRAE Guideline 0-2005. Several key additions have been made in this newer Annex B to NIBS Guideline 3-2006:

- First, this annex shows two parallel related flow diagrams, with major activities of the building development process on the left and key commissioning activities on the right,
- Second, the building design phases have been disaggregated into 3 sub phases – Schematic Design, Design Development, and Construction Documents.
- Third, most boxes within the right-hand Cx flow diagram have section numbers that link them to specific sections within the body of Guideline 3, in an effort to provide consistency between the text of the guideline and the sequences shown in the flow diagrams shown within this annex.

The reader is cautioned not to conclude from this annex that all boxes identified in as Cx activities are unique to the Cx process. Indeed, some of these activities have been included in traditional quality control procedures for some time. Unfortunately, most buildings have benefited from little or no quality control activity. Some buildings, have been blessed with more extensive quality control activities. For example, several members of the Guideline 3-2006 committee have indicated that their firms routinely accomplish a decent subset of the activities listed in this annex as a part of their normal design and construction services. However, the Cx process listed in this annex is much more comprehensive than traditional quality control services.

The reader is also cautioned not to conclude that it is sufficient to simply follow the Cx process outlined in this annex. It is also critical that the building development team have in depth expertise and experience about how building exterior enclosures are properly constructed, operated, and maintained. Following the process is not a substitute for solid expertise about the exterior enclosure.

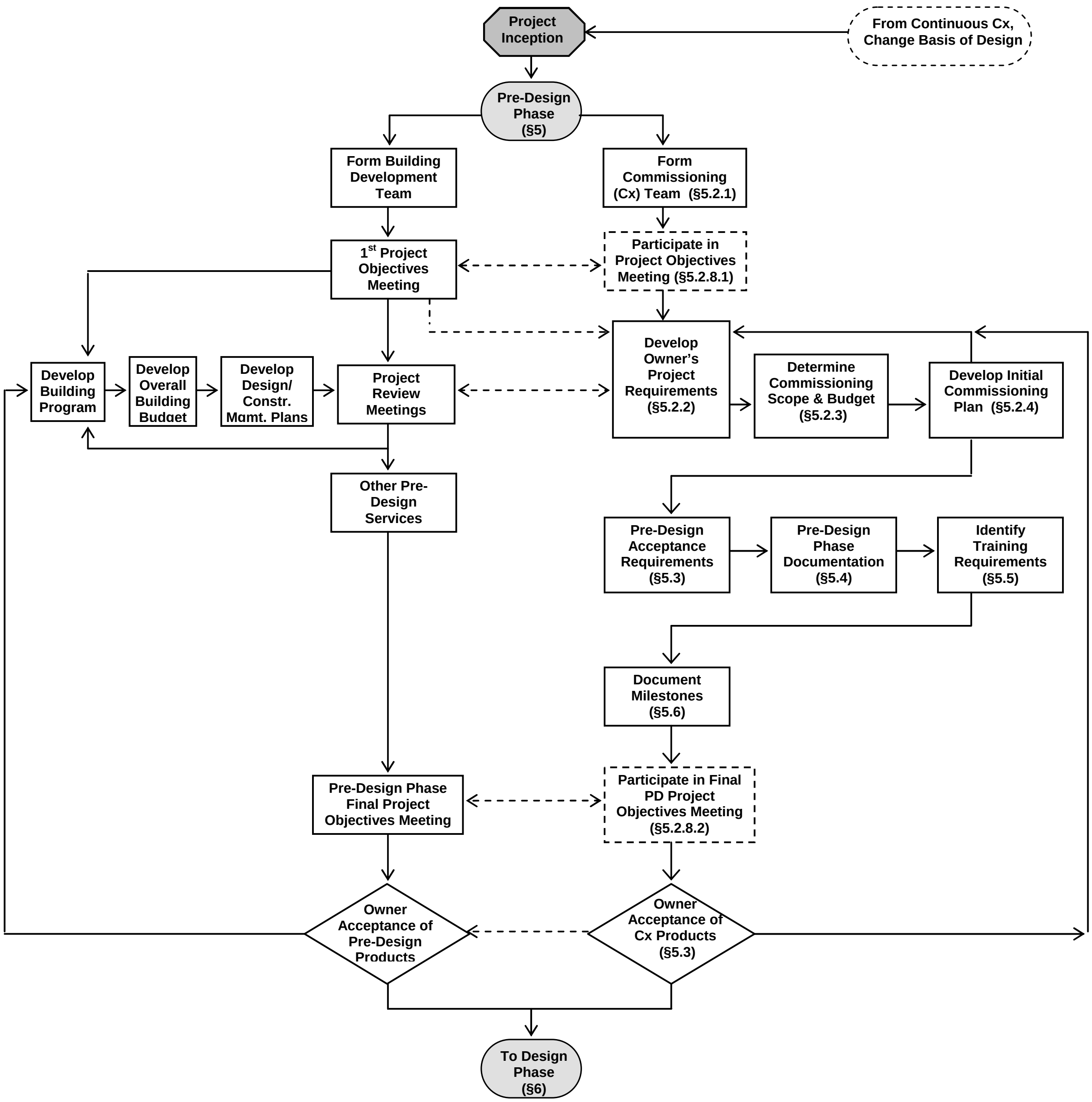
Credits

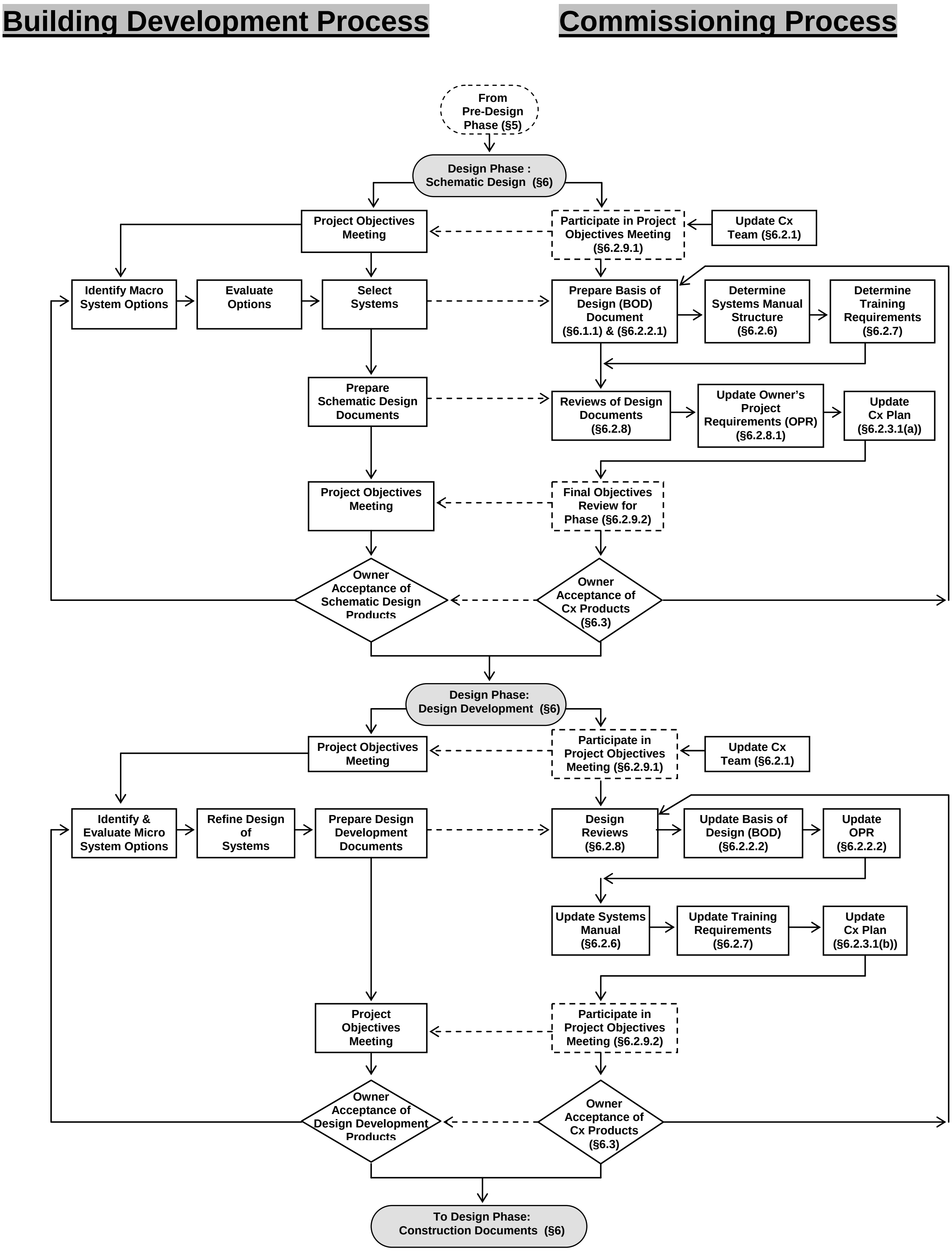
This annex has been developed by Joseph Deringer, starting from the Guideline 0-2005 flow diagram, and with substantial input from many members of the Guideline 3-2006 committee.

Five pages of Flow Diagrams begin on the following page.

Building Development Process

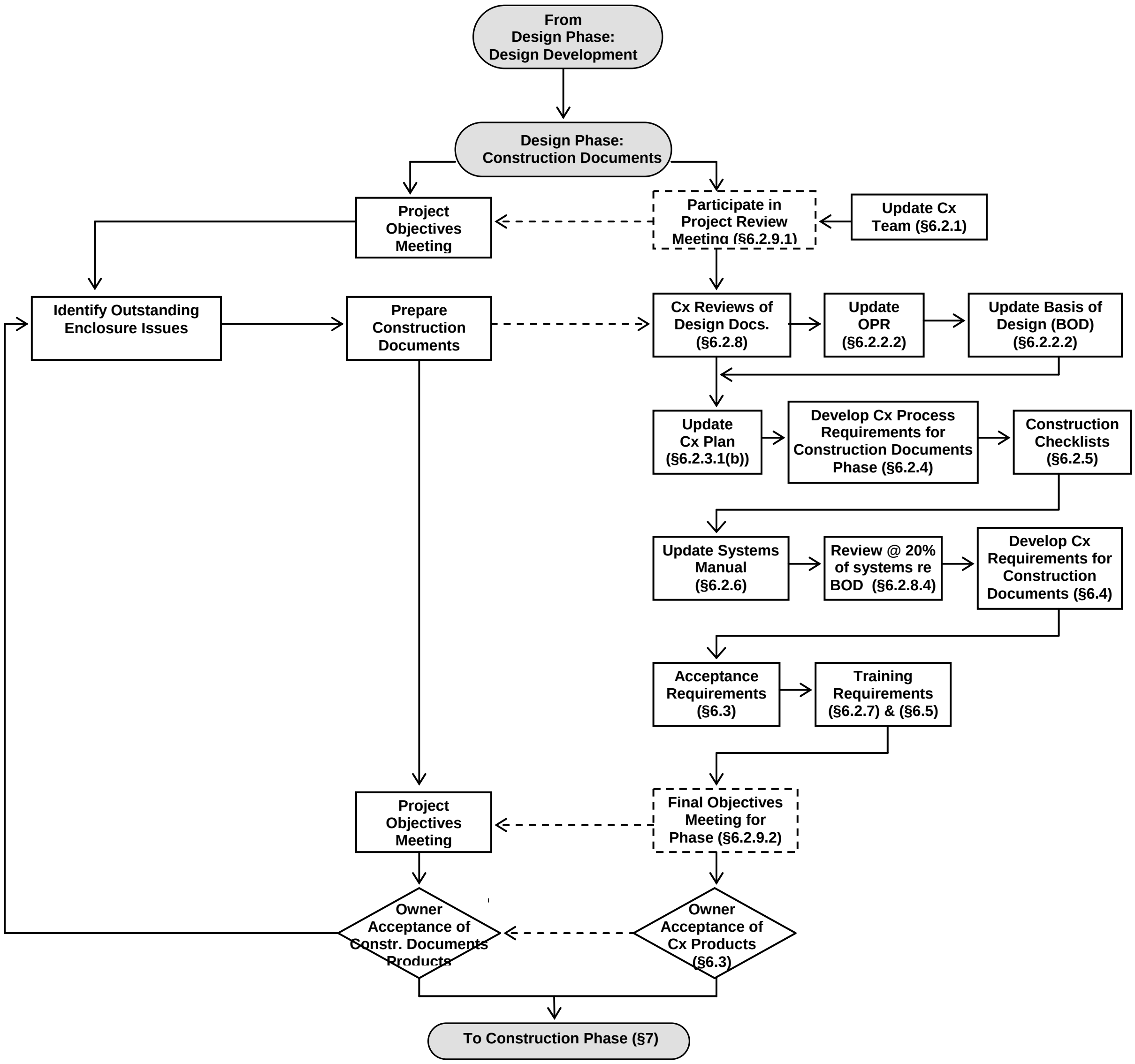
Commissioning Process




Building Development Process
Commissioning Process
From Pre-Design Phase (§5)
Design Phase : Schematic Design (§6)
Project Objectives Meeting
Participate in Project Objectives Meeting (§6.2.9.1)
Update Cx Team (§6.2.1)
Identify Macro System Options
Evaluate Options
Select Systems
Prepare Basis of Design (BOD) Document (§6.1.1) & (§6.2.2.1)
Determine Systems Manual Structure (§6.2.6)
Determine Training Requirements (§6.2.7)
Prepare Schematic Design Documents
Reviews of Design Documents (§6.2.8)
Update Owner's Project Requirements (OPR) (§6.2.8.1)
Update Cx Plan (§6.2.3.1(a))
Project Objectives Meeting
Final Objectives Review for Phase (§6.2.9.2)
Owner Acceptance of Schematic Design Products
Owner Acceptance of Cx Products (§6.3)
Design Phase: Design Development (§6)
Project Objectives Meeting
Participate in Project Objectives Meeting (§6.2.9.1)
Update Cx Team (§6.2.1)
Identify & Evaluate Micro System Options
Refine Design of Systems
Prepare Design Development Documents
Design Reviews (§6.2.8)
Update Basis of Design (BOD) (§6.2.2.2)
Update OPR (§6.2.2.2)
Update Systems Manual (§6.2.6)
Update Training Requirements (§6.2.7)
Update Cx Plan (§6.2.3.1(b))
Project Objectives Meeting
Participate in Project Objectives Meeting (§6.2.9.2)
Owner Acceptance of Design Development Products
Owner Acceptance of Cx Products (§6.3)
To Design Phase: Construction Documents (§6)

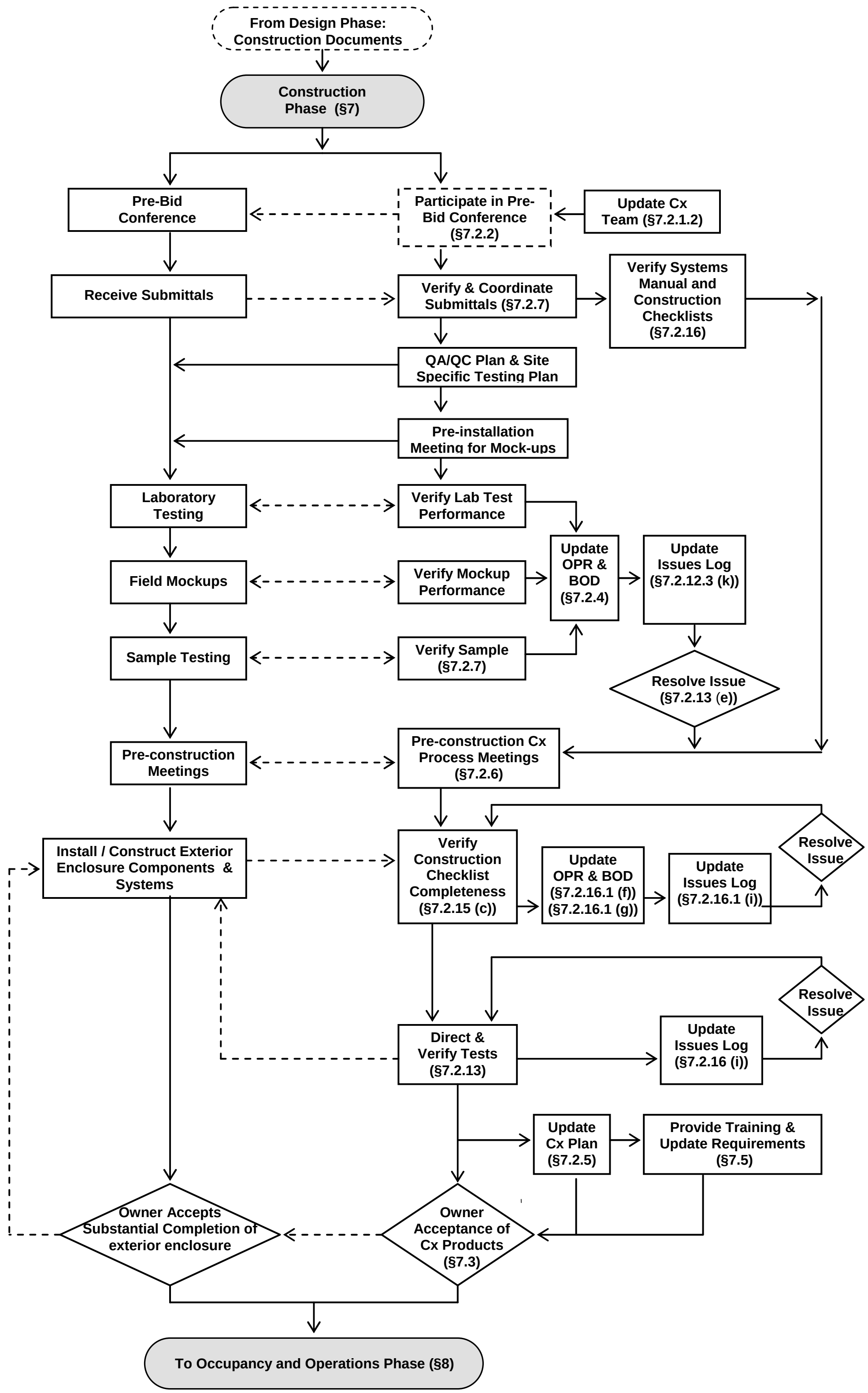
Building Development Process

Commissioning Process



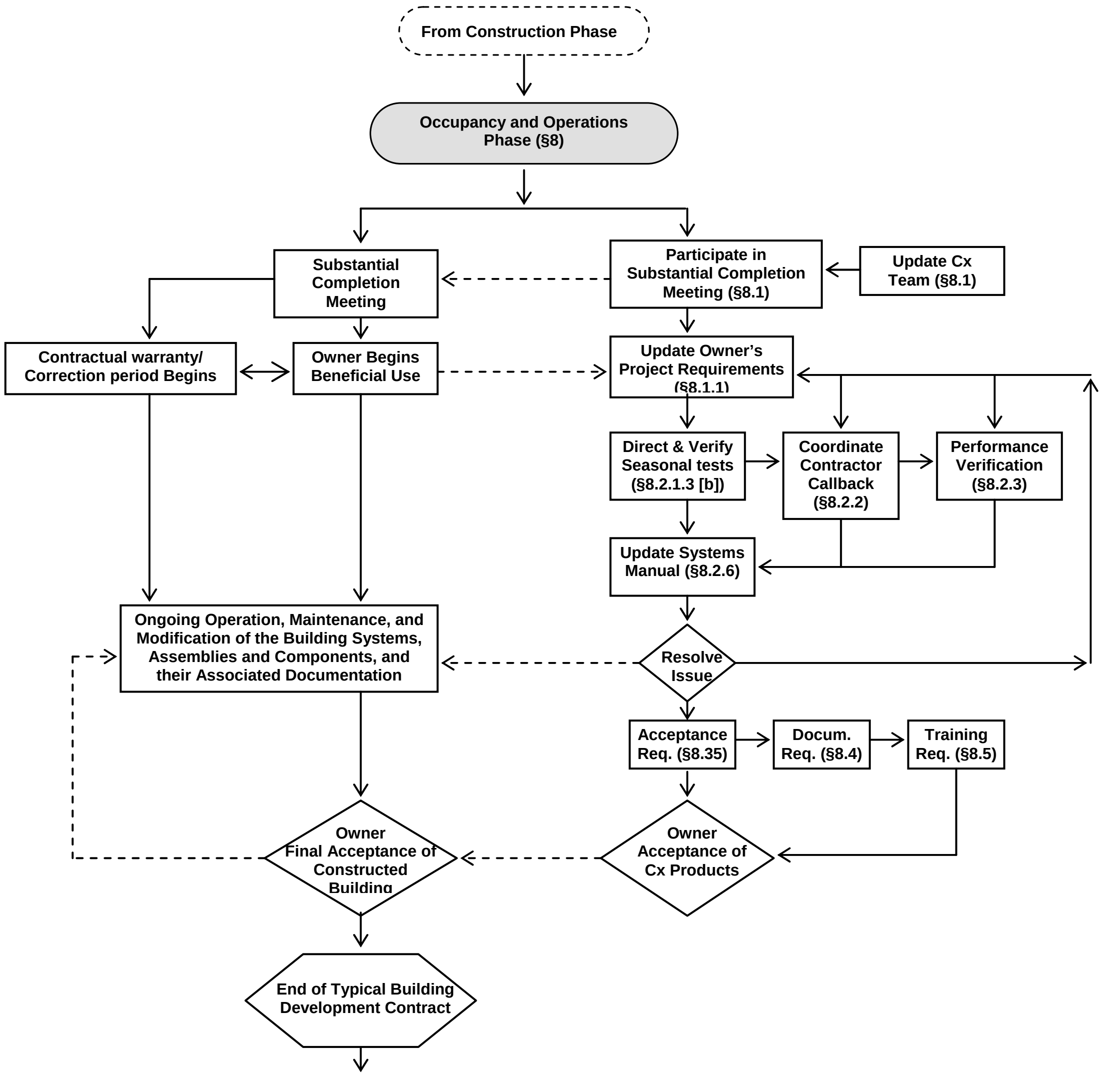
Building Development Process

Commissioning Process



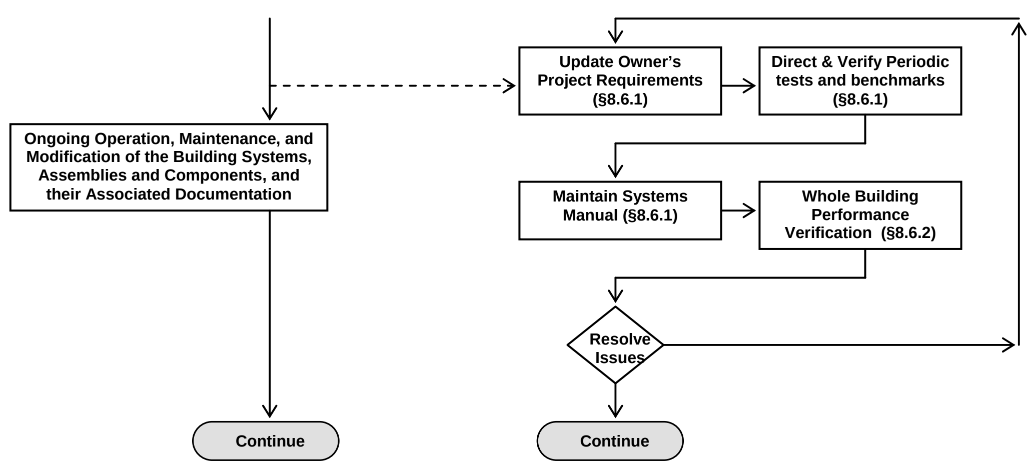
Building Development Process

Commissioning Process



Ongoing Building Operations

Constant Commissioning



Annex C: Costs and Benefits of Commissioning of the Building's Exterior Enclosure

Commentary: *This annex is intended to provide available information and examples about the costs and benefits of commissioning activities explicitly for the exterior enclosure.*

Credits: The first example of cost data specific to commissioning the building envelope has been provided in Section C1 by H. Jay Enck. The proposed structure for developing additional cost estimates in the future been provided in Section C2 by Chad Dorgan and Bill Nash.

C1 GENERAL ESTIMATE OF COSTS

C1.1 The level of effort of the Commissioning Process and size of the Commissioning Team for a given building can be strongly influenced by such factors as the owner's preferred level of building quality, the level of risk the owner will accept, as well as building size, type and complexity. Thus, it is difficult to develop general estimates of the level of effort required by the Commissioning Authority (CxA) and other members of the Commissioning Team.

C1.2 However, general rules of thumb can provide some guidance. Projects with construction budgets including tenant build out in excess of $20 Million typically require 0.002 of the construction budget for building exterior enclosure commissioning that is in addition to typical mechanical commissioning effort. This would be about $40,000 for a $20 million project.

C1.3 Projects including tenant build out less then $20 Million typically have increased costs due to reduction in scale with upper ranges for commissioning the building exterior enclosure from 0.003 to 0.01. This range of costs might result in $30,000 in cost to commission the exterior enclosure of a $10 million building (at 0.003) and $10,000 in cost to commission the exterior enclosure of a $10 million building (at 0.01)

C2 PLANNED STRUCTURE FOR ESTIMATING COSTS

C2.1 The GL3-2006 committee has not yet identified or developed a comprehensive set of cost estimates for commissioning the exterior enclosure. We plan to develop such estimates for next versions of these guidelines, and propose to use the structure in Table C.1 as a framework for developing such estimates. Table C.1 identified key commissioning activities for the exterior enclosure and relates the possible cost to the size of the building. Another key factor might be building complexity.

Table C.1 Proposed Structure for Exterior Enclosure Commissioning Cost Estimates

Cx Exterior Enclosure (EE) Item	Building Cost (Millions of $)			
	< $5 M	< $10 M	< $ 50 M	$ 100+ M
	Cx EE Costs (as Pct. of Construction $)			
Owner’s Project Requirements (OPR)	X	X	X	X
Basis of Design (BOD)	X	X	X	X
Design Review	X	X	X	X
Construction Checklist Creation	X	X	X	X
Site Visits (Construction Verification)	X	X	X	X
Testing	X	X	X	X
Documentation	X	X	X	X
Total	X	X	X	X

Annex D: Commissioning Process Documentation Matrix

Commentary

This annex is intended to provide examples of how to implement part of Guideline 3. This annex consists of examples of matrices that tabulate the documentation that can occur during the commissioning (Cx) process for the building exterior enclosure.

Two example documentation matrices are included at this time:

- o Annex D.1 contains a matrix for an office building with a developer-owner.
- o Annex D.2 contains a matrix for a small office building using a design-build process.

Additional example matrices for other building development cases for government and private sector buildings are planned for future versions of this annex.

In each matrix, each row indicates a key step in each phase of the building delivery process. For each row (step), the following elements are listed:

- o Cx document produced
- o Who provides the document
- o Who provides input to the document
- o Who reviews/ approves the document
- o Who uses the document
- o Comments are also provided in some cases.

The example documentation matrices are provided for information purposes only, and are not intended to be comprehensive representations or best practice examples. Practitioners applying the Commissioning Process should carefully follow both Guidelines 0-2005 and 3-2006 plus applicable commissioning technical guidelines tailored to their specific project requirements.

Credits

The example matrices in this annex have been developed by Paul Tseng, based on materials from GL 0-2005 and with review from members of the CxEE Committee.

Annex D.1: Office Building Example/Developer-Owner Commissioning Process Documentation

The following table summarizes the documents that are produced during the implementation of the Commissioning Process on a typical office building project involving a developer-owner.

Phase	Document	Input By	Provided By	Reviewed/ Approved By	Used By	Notes
Pre-Design (5.2.2)	Owner's Project Requirements	FM, O&M, Users, (Design Team)	Owner, CM	Owner-	CxA, FM, Design Team	Design Team not hired yet?
(5.2.3)	Scope, Milestones & Budget Allocation	Owner, FM, O&M	Owner, CM	Owner-	CxA, Design Team	Design Team not hired yet?
(5.2.4)	Commissioning Plan	Owner, FM, O&M, Users	CxA	Owner	CxA, Owner, Design Team	Design Team not hired yet?
(5.2.4.4)	Issues Log & Report	CxA	CxA	Owner	Design Team, Owner	Design Team not hired yet?
(5.3.1)	Acceptance & Commissioning Process Report	FM, O&M, Users, CxA	CxA	Owner	Owner	Close of Phase report
Design (6.1.1)	Owner's Project Requirements Update	FM, O&M, Users, (Design Team)	Owner, CM	Owner	CxA, FM, Design Team	
(6.2.2)	Basis Of Design	Design Team	Design Team	Owner, CxA	Design Team, CxA	
(6.2.3)	Commissioning Plan – Update	Owner, FM, O&M, Users	CxA	Owner	CxA, Owner, Design Team	
(6.2.4)	Construction Specifications for Commissioning	FM, O&M, Design Team, Owner	CxA	Owner	CxA, Design Team, Contractor	May also be provided by Owner's Rep
(6.2.4)	Construction Checklists	CxA, FM, O&M	CxA or Contractor	Owner	CxA, Design Team, Contractor	Contractor may not be hired yet
(6.2.5)	Systems Manual Outline -	Owner, FM, Design Team, Contractor	Design Team or CxA	Owner, CxA	Design Team, Contractor	Contractor may not be hired yet
(6.2.6)	Training Requirements In Specifications	O&M, FM, Owner	Owner or CxA	Owner	CxA, Design Team	
(6.2.7)	Commissioning – Focused Design Reviews	CxA, FM, O&M	CxA	Owner	Design Team	
	Issues Log & Report	CxA, FM, O&M	CxA	Owner	Design Team, Owner	
(6.3, 6.4)	Acceptance & Commissioning Process Report	CxA, FM, O&M	CxA	Owner	Owner, Design Team	Close of Phase report
Construction (7.2.2)	Pre-Bid Conference Commissioning Briefing	Owner, FM, O&M	CxA	Owner	Contractor, Design Team	
(7.2.4)	Owner's Project Requirements Update	FM, O&M, Users, (Design Team)	Owner, CM or CxA	Owner	CxA, FM, Design Team	
(7.2.5)	Commissioning Plan & Inspection Checklists Update	Owner, FM, O&M, Users, Contractor	CxA	CxA, Owner	CxA, Owner, Design Team, Contractors	

Phase	Document	Input By	Provided By	Reviewed/ Approved By	Used By	Notes
(7.2.6)	Pre-Construction Commissioning Process Briefing	Owner, FM, O&M, Contractor	CxA	Owner	Contractor, Design Team, Owner, FM	
(7.2.7)	Submittal Review Comments	Contractor	CxA	Owner, Design Team	Contractor	
(7.2.8)	Commissioning Milestone Schedule	Contractor, CxA	Contractor	CxA, Owner	Contractor, CxA, Owner	
(7.2.9)	Test Procedures	CxA, Contractor, Design Team	Contractor or CxA	CxA, Owner	Contractor, Design Team	
(7.2.10)	Test Data Reports	Contractor	CxA	CxA, Owner	Contractor	
(7.2.11)	Commissioning Meeting Record	CxA	CxA	All	All	
(7.2.12)	Site Visit Record	CxA	CxA	All	All	
(7.2.13)	Test Verification Record	CxA	CxA	Owner, CM	All	
(7.2.14)	Training Plans	Design Team, CxA, O&M, Contractor	Contractor or CxA	Owner, CxA	O&M, Users, Contractor	
(7.2.15)	Construction Phase Commissioning Process Report	CxA	CxA	Owner	Owner	Prior to Occupancy
(7.2.16)	Systems Manual Update	Design Team, CxA, O&M, Contractor	Contractor	Owner, CxA	O&M, Users	
(7.2.16)	Issues Log & Report	CxA	CxA	Owner, Design Team	Design Team, Owner, Contractor	
(7.2.17)	Basis of Design Update	CxA	CxA	N/A	CxA, Design Team, Contractor	
(7.4)	Construction Phase Acceptance & Commissioning Process Report	CxA	CxA	Owner	Owner	Close of Phase report
(7.5)	Training	FM, Design Team	Contractor	Owner., CxA	Owner	
Occupancy and Operations (8.2.1)	Owner's Project Requirements Compliance Update	O&M, Users, Design Team	CxA or Designer	Owner	CxA, Design Team, Contractors	
(8.2.3)	Seasonal Testing Record	FM, O&M, Users	CxA	Owner, CM	Owner, FM	
(8.2.4)	Deferred Training Record	FM, O&M, Users	CxA	Owner, CM	Owner, FM	
(8.3)	Acceptance & Commissioning Process Report	CxA	CxA	Owner	Owner	Final report
(8.4.1)	System Manual Update	FM, Design Team	CxA	Owner, FM	FM, O&M	
(8.4.2)	Continuous Commissioning Plan	O&M, Users, CxA	CxA or Owner	Owner, FM	Owner	
(8.5)	Training Update	FM, Design Team	CxA	Owner, FM	Owner	

Notes:

1. The term "contractor" is understood to refer to any of several entities that provide construction services. Depending upon the project, this could include, among others, the owner's representative, construction manager, design-builders, general contractors, and sub-contractors.

2. Abbreviations: CxA: Commissioning Authority; CM: Owner's Construction Manager; FM: Facility Manager; O&M: Operations and Maintenance personnel; OPR: Owner's Project Requirements.

Annex D.2: Small Building Example/Design-Build Commissioning Process Documentation

The following table summarizes the documents that are produced during the implementation of the Commissioning Process on a project.

Phase	Document	Input By	Provided By	Reviewed/ Approved By	Used By	Notes
Pre-Design (5.2.2)	Owner's Project Requirements	FM, O&M, Users, (Design Team)	Owner, DB	Owner-	CxA, FM, Design Team	Design Team not hired yet?
(5.2.3)	Scope, Milestones & Budget Allocation	Owner, FM, O&M	Owner, DB	Owner-	CxA, Design Team	Design Team not hired yet?
(5.2.4)	Commissioning Plan	Owner, FM, O&M, Users	CxA	Owner	CxA, Owner, Design Team	Design Team not hired yet?
(5.2.4.4)	Issues Log & Report	CxA	DB with CxA	Owner	Design Team, Owner	Design Team not hired yet?
(5.3.1)	Acceptance & Commissioning Process Report	FM, O&M, Users, CxA	CxA	Owner	Owner	Close of Phase report
Design (6.1.1)	Owner's Project Requirements Update	FM, O&M, Users, (Design Team)	Owner, DB	Owner	CxA, FM, Design Team	
(6.2.2)	Basis Of Design	Design Team	Design Team	Owner, CxA	Design Team, CxA	
(6.2.3)	Commissioning Plan - Update	Owner, FM, O&M, Users	CxA	Owner	CxA, Owner, Design Team	
(6.2.4)	Construction Specifications for Commissioning	FM, O&M, Design Team, Owner	CxA	Owner	CxA, Design Team, Contractor	May also be provided by Owner's Rep
(6.2.4)	Construction Checklists	CxA, FM, O&M	CxA or Contractor	Owner	CxA, Design Team, Contractor	Contractor may not be hired yet
(6.2.5)	Systems Manual Outline -	Owner, FM, Design Team, Contractor	Design Team or CxA	Owner, CxA	Design Team, Contractor	Contractor may not be hired yet
(6.2.6)	Training Requirements In Specifications	O&M, FM, Owner	Owner or CxA	Owner	CxA, Design Team	
(6.2.7)	Commissioning – Focused Design Reviews	CxA, FM, O&M	CxA	Owner	Design Team	
	Issues Log & Report	CxA, FM, O&M	CxA	Owner	Design Team, Owner	
(6.3, 6.4)	Acceptance & Commissioning Process Report	CxA, FM, O&M	CxA	Owner	Owner, Design Team	Close of Phase report
Construction (7.2.2)	Pre-Bid Conference Commissioning Briefing	Owner, FM, O&M	CxA with DB	Owner	Contractor, Design Team	
(7.2.4)	Owner's Project Requirements Update	FM, O&M, Users, (Design Team)	DB or CxA	Owner	CxA, FM, Design Team	
(7.2.5)	Commissioning Plan & Inspection Checklists Update	Owner, FM, O&M, Users, Contractor	CxA	CxA, Owner	CxA, Owner, Design Team, Contractors	

Phase	Document	Input By	Provided By	Reviewed/ Approved By	Used By	Notes
(7.2.6)	Pre-Construction Commissioning Process Briefing	Owner, FM, O&M, Contractor	DB or CxA	Owner	Contractor, Design Team, Owner, FM	
(7.2.7)	Submittal Review Comments	Contractor	CxA	Owner, Design Team	Contractor	
(7.2.8)	Commissioning Milestone Schedule	Contractor, CxA	Contractor	CxA, Owner	Contractor, CxA, Owner	
(7.2.9)	Test Procedures	CxA, Contractor, Design Team	Contractor or CxA	CxA, Owner	Contractor, Design Team	
(7.2.10)	Test Data Reports	Contractor	CxA	CxA, Owner	Contractor	
(7.2.11)	Commissioning Meeting Record	CxA	CxA	All	All	
(7.2.12)	Site Visit Record	CxA	CxA	All	All	
(7.2.13)	Test Verification Record	CxA	CxA	Owner, DB	All	
(7.2.14)	Training Plans	Design Team, CxA, O&M, Contractor	Contractor or CxA	Owner, CxA	O&M, Users, Contractor	
(7.2.15)	Construction Phase Commissioning Process Report	CxA	CxA	Owner	Owner	Prior to Occupancy
(7.2.16)	Systems Manual Update	Design Team, CxA, O&M, Contractor	Contractor	Owner, CxA	O&M, Users	
(7.2.16)	Issues Log & Report	CxA	DB	Owner, Design Team	Design Team, Owner, Contractor	
(7.2.17)	Basis of Design Update	CxA	Design Team	N/A	CxA, Design Team, Contractor	
(7.4)	Construction Phase Acceptance & Commissioning Process Report	CxA	CxA	Owner	Owner	Close of Phase report
(7.5)	Training	FM, Design Team	Contractor	Owner., CxA	Owner	
Occupancy and Operations (8.2.1)	Owner's Project Requirements Compliance Update	O&M, Users, Design Team	DB or Designer	Owner	CxA, Design Team, Contractors	
(8.2.3)	Seasonal Testing Record	FM, O&M, Users	CxA	Owner, DB	Owner, FM	
(8.2.4)	Deferred Training Record	FM, O&M, Users	CxA	Owner, DB	Owner, FM	
(8.3)	Acceptance & Commissioning Process Report	CxA	CxA	Owner	Owner	Final report
(8.4.1)	System Manual Update	FM, Design Team	CxA	Owner, FM	FM, O&M	
(8.4.2)	Continuous Commissioning Plan	O&M, Users, CxA	CxA or Owner	Owner, FM	Owner	
(8.5)	Training Update	FM, Design Team	CxA	Owner, FM	Owner	

Notes:

1. The term “contractor” is understood to refer to any of several entities that provide construction services. Depending upon the project, this could include, among others, the owner’s representative, construction manager, design-builders, general contractors, and sub-contractors.

2. Abbreviations: CxA: Commissioning Authority; DB: Owner’s Design-Build Manager; FM: Facility Manager; O&M: Operations and Maintenance personnel; OPR: Owner’s Project Requirements.

Annex F: Roles and Responsibilities Matrix

Commentary

This annex is intended to provide an overview perspective of the typical roles and responsibilities of all building development team members in the commissioning (Cx) process for the building exterior enclosure.

The information in this Annex is related to the information presented in Annex D.

Credits

This annex has been developed by Paul Tseng with input from many members of the Guideline 3-2006 committee.

Phase & GL-3 Section number	Document	Owner	CxA	Design Team						ExEncl		Contractors					Specialists								Bldg Ops			Notes
		Owner, or Owner's Representative	Commissioning Authority	Architect	Structural Engineer	Mechanical Engineer	Electrical Design Engineer	Lighting Design professioinal	Interior Systems Design Prof.	Exterior Enclosure Consultant	Ext. Enclosure Manufacturers	Construction Manager	General contractor	Exterior Enclosure Contractors	Testing contractor	Electrical Contractor	Indoor Air Quality Specialist	Acoustic specialist	Vibratoin specialist	Moisture/mildew specialist	Measurement/verification specialis	Information technology specialist	Physical security specialist	Blast (and Chem-bio) Security	Facilities management	Facilities engineer (O&M)	Occupants	
Pre-Design																												
5.2.2	Owner's Project Requirements	**A**	**R**	**I**	I	I	I	I	I	**I**		**P**													**I**	**I**	**I**	Design Team not hired yet?
5.2.3	Allocation	**P/A**	**U**	**U**	U	U	U	U	U			P													**I**	**I**		Design Team not hired yet?
5.2.4	Commissioning Plan	**A**	**P**	I	I	I	I	I		I															**I**	**I**	**I**	Design Team not hired yet?
5.2.4.4	Issues Log & Report	R	**P**	U	U	U	U	U		I	U	**U**	**U**	**U**	U	U									I	I		Design Team not hired yet?
5.3.1	Acceptance & Commissioning Process Report	R	**P**	U	U	U	U	U		U	U	U	**U**	U	U										**U**	U		Close of Phase report
Design																												
6.1.1	Owner's Project Requirements (OPR) Update	**A**	**P**	**I**	I	I	I	I		**I**		I					I			I					I	I	I	
6.1.1.1	OPR - Schematic Design Phase	**A**	**P**	**I**	I	I	I	I		**I**		I					I	I	I	I	I	I	I	I	I	I	I	
6.1.1.2	OPR - Design Development Phase	**A**	**P**	**I**	I	I	I	I		**I**		I					I			I					I	I	I	
6.1.1.3	OPR - Construction Document Phase	**A**	**P**	**I**	I	I	I	I		**I**		I					I			I					I	I	I	
6.2.2	Basis of Design	**A**	**R**	**P**	I	I	I	I		**I**							I			I					I	I	I	
6.2.2.1	BOD - Schematic Design Phase	**A**	**R**	**P**	I	I	I	I		**I**							I	I	I	I	I	I	I	I	I	I	I	
6.2.2.2	BOD - Design Development Phase	**A**	**R**	**P**	I	I	I	I		**I**							I			I					I	I	I	
6.2.2.3	BOD - Construction Document Phase	**A**	**R**	**P**	I	I	I	I		**I**							I			I					I	I	I	
6.2.3	Commissioning Plan - Update	**R**	**P**	U						**U**	U	U													**I**	I		
6.2.4	Construction Specifications for Commissioning	**R**	**P**	**U**						**I**	I	R													I	I		May also be provided by Owner's Rep
6.2.4	Construction Checklists	**R**	**A**	R						R	**I**	R													I	I		Contractor may not be hired yet
6.2.5	Systems Manual Outline -	**A**	**P**	I	I	I	I	I		**I**		R													**U**	U		Contractor may not be hired yet
6.2.6	Specifications	**A**	**R**							**I**		R						I		I					I	I		
6.2.7	Commissioning -Focused Design Reviews	**A**	**P**	**U**	U	U	U	U		I		U						I		I					I	I	I	
	Issues Log & Report	**A**	**P**	**U**	U	U	U	U		I		U						I		I					I	I		
6.3, 6.4	Acceptance & Commissioning Process Report	**A**	**P**	U	U	U	U	U		I		I						I		I					I	I	I	Close of Phase report

Key

P	**Provided by**
A	**Approved by**
R	**Reviewed by**
R/A	**Reviewed/Approved by**
I	**Input from**
U	**Used by**

Key

P	**Provided by**
A	**Approved by**
R	**Reviewed by**
R/A	**Reviewed/Approved by**
I	**Input from**
U	**Used by**

		Owner	CxA	Design Team						ExEncl		Contractors					Specialists								Bldg Ops			
Phase & GL-3 Section number	**Document**	Owner, or Owner's Representative	Commissioning Authority	Architect	Structural Engineer	Mechanical Engineer	Electrical Design Engineer	Lighting Design professioinal	Interior Systems Design Prof.	Exterior Enclosure Consultant	Ext. Enclosure Manufacturers	Construction Manager	General contractor	Exterior Enclosure Contractors	Testing contractor	Electrical Contractor	Indoor Air Quality Specialist	Acoustic specialist	Vibratoin specialist	Moisture/mildew specialist	Measurement/verification specialis	Information technology specialist	Physical security specialist	Blast (and Chem-bio) Security	Facilities management	Facilities engineer (O&M)	Occupants	**Notes**
Construction																												
7.2.2	Pre-Bid Conference Commissioning Briefing	R	**P**	I						I		**U**						I		I					I			
7.2.4	Owner's Project Requirements	**A**	U	**P**								U													I			
7.2.5	Commissioning Plan & Inspection Checklists Update	**R**	**P**	I						I	U	U	U	**U**	U			I		I					I			
7.2.6	Pre-Construction Commissioning Process Briefing	**A**	**P**	I						I	U	U	U	**U**	U			I		I					I			
7.2.7	Submittal Review Comments	R	**P**	U						I	U	U	U	U	U			I		I					I			
7.2.8	Commissioning Milestone Schedule	**A**	**P**	I						I	U	**U**	**U**	U	U			I		I					I			
7.2.9	Test Procedures	**A**	**P**	I						**I**	I	U		**U**	**U**		I	I	I	I			I	I	**I**			
	Test Procedures - Components	**A**	**P**	I						**I**	I	U		**U**	**U**		I	I	I	I			I	I	**I**			
	Test Procedures - Systems	**A**	**P**	I						**I**	I	U		**U**	**U**		I	I	I	I			I	I	**I**			
	Mockups	**A**	**R**	I						**I**	I	U		**P**	**U**		I	I	I	I			I	I	**I**			
7.2.10	Test Data Reports	**A**	**R**	I						I	**I**	U		**U**	**P**		I			I					I			
7.2.11	Commissioning Meeting Record	**A**	**P**	R						R	U	R	**U**	**U**	U		R	R	R	R					R	R		
7.2.12	Site Visit Record	**A**	**P**	R						R	U	R	**U**	U	U		R	R	R	R					R	R		
7.2.13	Test Verification Record	R	**A**	R						R	U	U	P	P	**P**		R	R	R	R					R	R		
7.2.14	Training Plans	R	**P**	I						I		**U**	U	U	U		I			I					**A**	R		
7.2.15	Construction Phase Commissioning Process Report	A	**P**	I						I	U	U	U	U	U		I			I			I	I	R	R		Prior to Occupancy
7.2.16	Systems Manual Update	**A**	**P**	I						I	I	I	I	I	**I**		I			I			I	I	R	R		
7.2.16	Issues Log & Report	**R**	**P**							I	U	**U**	U	**U**	U		I			I					I	I		
7.2.17	Basis of Design Update	**R**	R	**P**						I	U	U	U	U	U		I			I			I	I	I	I		
7.4	Construction Phase Acceptance & Commissioning Process Report	**A**	**P**	R						I	U	U	U	U	U		I			I			I	I	I	I		Close of Phase report
7.5	Training	**A**	**R**	R						I		U	P	**P**	P										U	U		
Occupancy and Operations																												
8.2.1	Owner's Project Requirements Compliance Update	**A**	**P**	R		I				I		I	R	I			I				I				**A**	R		
8.2.3	Seasonal Testing Record	A	**R**	R						I		R	R	**P**	U		I				I				**A**	R		
8.2.4	Deferred Training Record	A	R							I			R	**P**	U		I				I				**A**	R		
8.30	Acceptance & Commissioning Process Report	**A**	**P**	R								**R**	U	U	U		I				I				A	R		Final report
8.4.1	System Manual Update	**A**	**P**	I						I		I	I	I	I		I				I				A	R		
8.4.2	Continuous Commissioning Plan	A	**P**	I						I		R	I	I	I		I				I				**A**	R		
8.5	Training Update	A	**P**	I								R		R											**A**	R		

Annex J: Owner's Project Requirements (OPR) for the Building's Exterior Enclosure

Commentary: This annex is intended to provide information and examples about the structure and contents of the Owner's Project Requirements as they apply to the building's exterior enclosure.

This annex contains one sub-annex: An example checklist of contents of the OPR for the building exterior enclosure. This is the type of product used in practice by firms that place high priority on commissioning activities for the exterior enclosure.

Credits: The example checklist in Annex J.1 has been provided by David Altenhofen.

ANNEX J.1: Exterior Enclosure Checklist for Owner's Project Requirements (OPR)

1. Building Objectives

List the objectives that are unique to the exterior enclosure and that expand upon the objectives and goals described in Whole Building Commissioning.

2. Site Description and Requirements

List criteria that have a major influence on the Architectural development of the building design. Coordinate with Site/Civil.

2.1. Neighborhood / Context

Describe the influence of the project site, neighborhood and context on the building design.

2.2. Existing Buildings

Describe existing buildings and their influence on the design.

2.3. Master Plan

Describe existing or in progress master planning issues which affect the design

2.4. Circulation / Access

Describe the opportunities and constraints imposed by circulation issues and required access.

Major Building Access:

Secondary Building Access:

Deliveries and Services:

- Trash Docks and Compactors.
- Kitchen, Cafeteria or other food service Deliveries and Services.
- Lab, Animal, GMP or other special Deliveries and Services.
- Ambulance or Emergency Service.

2.5. Zoning

Describe the allowable building footprint, maximum height, FAR, and other zoning issues that affect the design. Coordinate with the Site/Civil Section.

Buildable Dimensions and Area:

Maximum FAR:

Maximum Height:

		Upper Level Setbacks:
2.5.1.	Zoning or Planned Unit Development Restrictions on Materials or Design	Describe any special restrictions on the design of the building such as exterior materials, roof shapes, percent glazed area, etc.
2.5.2.	Local, Neighborhood or Community Review Boards or Approvals	Describe any special approvals of the building design that may be required.

3. Building Code

3.1.	***Authority Having Jurisdiction and Codes in Affect***	[City of [ ]]
		[2003 International Building Code with Amendments]
		[XXXX NFPA 101 Fire Prevention Code]
		[Plumbing Code]
		[Mechanical Code]
		[Electrical Code]
3.1.1.	Construction Types	Type:
		Fully Sprinkled: [Yes.] [No.]
		Structural Fire Ratings.
3.1.2.	Allowable Areas	Tabular Allowable Area per Floor (Table 503): [ ] SF.
		Frontage Increase (506.2): [ ] percent.
		Sprinkler Increase (506.3): [ ] percent.
		Allowable Area per Floor (506.1): [ ]SF.
		Allowable Total Building Area:
3.1.3.	Allowable Height	Tabular Allowable Height (Table 503): [ ] FT.
		Increase (XXXX): [ ] percent.

Allowable Height (506.1): [ ]SF.

3.1.4. [Special Conditions Such As An Atrium]

4. Sustainability

Describe the Owner's and Design Professional's criteria for sustainability for the project. Describe any specific programs or measuring tools that may be required to measure energy conservation issues such as LEED ratings or ASHRAE 90.1. Coordinate with section below for enclosure thermal performance criteria.

4.1. Energy Conservation

4.2. Life Cycle Costing

4.3. Recycled Materials

5. Existing Facilities

Identify special criteria for renovations, restorations, additions, alterations or any other work on an existing facility. Coordinate this overall section with the "Existing" paragraphs in the remainder of the OPR. Coordinate with the code analysis and life safety section.

Note that building code, energy conservation and accessibility requirements may affect areas of the building beyond the owners identified scope.

Note that any change of use or occupancy frequently triggers additional code requirements. Adding conference rooms or cafeterias to existing office buildings is a commonly missed change of use.

6. Program

6.1. Functional Criteria

Describe needs for building functions and arrangements of major areas. If separate Criteria or Program Report is included, give a basic list of program requirements here.

6.1.1. Primary Functions

6.1.2. Support Functions

6.2. Adjacencies

Describe requirements for functional and physical adjacencies. Refer to attached diagrams.

6.3. Program Scope

Tabulate preliminary Net and Gross Areas.

6.4. Space Criteria or Program Report

Refer to detailed criteria such as Room Data Cards, Space Criteria Sheets, Lab Cards, or Program Report provided in Appendix.

7. Exterior Enclosure Thermal Performance Criteria

Identify applicable code requirements for thermal performance of exterior enclosure. Many jurisdictions are adopting the IBC, which requires compliance with the International Energy Code and/or ASHRAE/IESNA Standard 90.1. If more than code is applicable, identify requirements of each and indicate most restrictive. Verify if required value is for insulation only or for the entire assembly.

Note that ASHRAE 90.1 and IEC allow alternative analysis methods to determine compliance in lieu of the prescriptive method. Identify if alternative methods may be utilized.

Coordinate this section carefully with the appropriate Architectural Criteria Worksheets and with the Mechanical Engineers.

7.1. Applicable Codes

[State Energy Code XXXXX] [International Energy Code, 200XX] [ASHRAE/IESNA Standard 90.1 [19XX] [20XX]] [
]

7.2. Roofs

Identify minimum performance values for roof assembly.

- ✓ Minimum [R] [U] Value:
- ✓ [Color] [Reflectivity] [Emissivity]:

7.2.1. Skylights

Identify minimum performance values and maximum area of skylights.

- ✓ Maximum Area:
- ✓ Minimum [R] [U] Value at Center of Glass:
- ✓ Minimum [R] [U] Value of Frame:

7.3. Wall Criteria

7.3.1. Opaque Wall Area

Identify minimum performance values for wall assemblies.

- ✓ Minimum [R] [U]:

7.3.2. Glazed Wall Area

Identify minimum performance values and maximum area of windows, curtainwall and storefront.

- ✓ Maximum Area:
- ✓ Minimum [R] [U] Value at Center of Glass:
- ✓ Minimum [R] [U] Value of Frame:

7.3.3. Exterior Doors

Identify minimum performance values and maximum area of exterior doors:

- ✓ Maximum Area:
- ✓ Minimum [R] [U] Value:

7.4. Foundation and Below-Grade Walls

Identify minimum performance values for foundations and below-grade wall assemblies.

- ✓ Minimum [R] [U] Value:
- ✓ Minimum Coverage/Extent:

7.5. Slabs and Edge of Slabs

Identify minimum performance values for slabs and edges of slabs.

- ✓ Minimum [R] [U] Value:
- ✓ Minimum Coverage/Extent:

7.6. Soffits

Identify minimum performance values for soffit assemblies.

- ✓ Minimum [R] [U] Value:

7.7. Alternate Compliance

Identify alternatives to the prescriptive requirements listed above. The two listed below are available in ASHRAE 90.1 and by reference, in 2000 IEC. Customize for project.

7.7.1. Enclosure Method

The ASHRAE 90.1 enclosure analysis method allows comparison of the proposed building against a model building matching the size and shape of the proposed building but with each assembly matching the prescriptive criteria listed above. Essentially, this method allows increasing insulation in one part of a building to make up for less performance on another, i.e. one can increase the roof insulation to allow larger skylights. The architect will have to run a simple computer program analysis for this comparison.

7.7.2. Total Building Method

The ASHRAE 90.1 total building analysis method allows comparison of the proposed building against a model building matching the size and shape of the proposed building but with a prescribed maximum energy usage. This method allows maximum flexibility in design by making trade-offs between enclosure performance and mechanical system performance, i.e. one can increase the amount of glazing by improving the efficiency of the HVAC system.

Note that this analysis requires the mechanical engineer to run a relatively complex computer analysis. The entire project team must buy into this task before assuming that this analysis can be used.

8. Exterior Enclosure Structural Criteria

Identify the structural criteria required for the project. Coordinate with the Structural OPR if provided separately as part of Whole Building OPR

8.1. Loads and Serviceability Criteria Standards

American Society of Civil Engineers, "Minimum Design Loads for Buildings and Other Structures" (ASCE 7).

General Services Administration (GSA) "Facilities Standards for the Public Buildings Service - Metric Version" PBS-PQ100.1.

8.2. Progressive Collapse

Identify need for progressive collapse analysis.

Progressive collapse will be analyzed in accordance with Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects – November 2000

8.3. Enclosure Loads

8.3.1.	Soil and Foundation Loads	Identify applicable bearing loads of soils and rock from geotechnical report. Identify loads applied to enclosure from soil and ground water.
8.3.2.	Roof Live Loads	Minimum live load shall be XXXXXX. Roof live loads [will] [will not] be reduced per code." Service Load Paths - Specific areas will be identified and designed for appropriate loadings to allow for movement of mechanical equipment components across the roof if required. The values of the loads will be based upon the type of equipment to be moved as identified when the building program is detailed.
8.3.3.	Roof Ponding Loads	Roofs will be designed for the weight of ponded water considering all primary drainage is blocked. The depth of ponded water shall include the deflection of the roof structure and the distance above the scupper base as required to account for flow. The height of flow will be based on the serviced area of roof, the appropriate volume of rainwater and the size of the scupper.
8.3.4.	Snow Load	The ground snow load (p_g) established by Code for the Project site is XXXXXXX. Importance factor (I_s) of XXXXXXXX in calculating the snow loads. Exposure factor (C_e): XXXX in calculating the snow loads based on a XXXXX exposure category X. Thermal factor (C_t): XXXXX in calculating the snow loads based on XXXXXXXXXXXX. Calculated "flat roof" snow load (p_f): XXXXXX. Snow Drifting – Adjacent to vertical projections, such as parapets, changes in roof elevation, etc., the snow load will be increased above the "flat roof" value in conformance with Code established parameters. Specific snowdrift values will be determined after development of the final roof configuration.

8.4. Wind Loads

The Basic Wind Speed established by Code for the project site is XXXXX.

Importance factor: [Increase] [decrease] the wind load based on an importance factor of XXXX.

Exposure category: Exposure X.

8.4.1. Wind Loads on the Structural Frame

Height	Load
XXXX - XXXX	XXX
XXXX - XXXX	XXX
XXXX - XXXX	XXX

8.4.2. Wind Load on Cladding

Tributary Area	Load
XXXX - XXXX	XXX
XXXX - XXXX	XXX
XXXX - XXXX	XXX

8.5. Seismic Loads

Identify Seismic Performance Category and the Components Performance Criteria factor.

8.6. Movement

Identify movement-limiting design criteria in order to minimize the degradation of materials applied or attached to the structure and/or to control the perception of movement by occupants.

8.7. Deflection

Structural elements will be designed within the deflection control limits below except where the material codes require more restrictive criteria.

Framing Element	Loading	Control Criteria
Floor Member	Live + Dead Load	Span/240
Floor Member	Live Load	Span/360
Floor Member Supporting Glass	Superimposed Load	Span/480
Floor Member Supporting Masonry	Superimposed Load	Span/600
Typical Roof Member	Live + Dead Load	Span/180
Typical Room Member	Live Load	Span/240

Elevator Supports	Live Load	Span/1666
Sunscreens & Canopies	Live Load	Span/175

8.7.1. Drift

Interstory (between any two floors) and total drift control limits: Height/XXX.

Drift due to seismic loads: XXXXX.

9. Roofing

9.1. Roofing Standards

- NRCA Roofing and Waterproofing Manual.
- SMACNA Architectural Sheet Metal Manual.
- SPRI.
- FM Global Loss Prevention Sheet 49.

9.2. Roofing Criteria

- Owner's Standards*: Identify if Owner has a standard or preference for type, name brand, etc. Does the Owner have a national account with roofing manufacturer?*
- Owner's Insurance Requirements: *Identify insurance requirements, especially Factory Mutual requirements*
- Owner's Warranty Requirements: *Identify the Owners requirements and attitudes towards roof system Warranties. Include provisions that Warranties in not way stop roof leaks, but only outline the manufacturer's duties in the event of a roof leak.*
- Roof Substrate: Identify roof substrate material (i.e. metal deck, concrete, wood, gypsum, precast). Is structure sloped to drains? What are spans and maximum deflections?
- Structural Capacity of the Roof: Identify structural capacity of roof substrate and structure, especially on re-roofing projects and when ballasted systems are being considered. Coordinate with Structural Engineer.
- Exterior Conditions: Identify the exterior relative humidity and temperature design criteria determined by the mechanical engineer.
    - Winter Exterior Design Temperature:

  - o Winter Exterior Design Relative Humidity:
  - o Summer Exterior Design Temperature:
  - o Summer Exterior Design Relative Humidity:

- Interior Conditions: Identify the interior relative humidity and temperature design setpoints determined by HVAC requirements.
  - o Winter Interior Temperature:
  - o Winter Interior Relative Humidity:
  - o Summer Interior Temperature:
  - o Summer Interior Relative Humidity:
  - o Interior Pressure Relative to Exterior:
- Thermal Performance Criteria: Refer to section above.
- Anticipated Rooftop Traffic: *Identify the anticipated amount of traffic required on the roof (i.e., occasional access by roof maintenance workers or constant access by mechanical maintenance workers). Note: If there is any traffic other than maintenance, the surface will be considered a plaza deck, the membrane will be considered waterproofing and any roofing warranty could be voided.*
- Chemical Reactions: *Identify any exhaust on or near roof except normal building exhaust. Note that grease from kitchen exhaust hoods can damage built-up roofs and EPDM roofs*
- Clients Environmental and Safety Issues: *Identify of any occupants or functions in the buildings that are sensitive to fumes or odors. Identify potential HVAC air intakes for entraining of odors. Identify issues related to use of fired kettles or open flames required for some systems.*
- Visibility: *Is the roof visible from above?*
- Reliability: *Identify the required reliability of the roof system based on the relative importance or value of contents of buildings? (A computer center versus maintenance shed, for example).*
- Physical Damage: Identify significant skylights or adjacent glazing that may be broken by wind propelled loose ballast including on adjacent buildings. Identify damage from falling ice.
- Future Roof Work: Identify future roof penetrations, rooftop equipment, roof plazas, or conversion of roof to occupied floor.

- Life Cycle Cost: Identify the importance of first cost versus life cycle cost. Identify methodology for life cycle cost analysis and minimum payback period. Note the relative difficulty of re-roofing. A low-rise building surrounded by parking with a 9-5, 5-day operation is easy to re-roof. A high-rise, secured facility with 24/7 operation in an urban setting will be much more difficult to re-roof because of logistical problems.
- Fire Rating: Identify the fire rating of the roof/ceiling assembly and the flame spread classification of the roof system.
  - Fire Stopping: Identify requirement for protection of openings, construction joints and through penetrations of roof system. Protection is sometimes required within certain distances of fire rated wall assemblies.
- Expansion Joints and Roof Dividers: Identify joints required in the roof system including building expansion joints and roof area dividers.
- Drain Sizing: Identify building code and industry standard criteria for sizing of drains, gutters, overflows and scuppers. See SMACNA and plumbing codes. Coordinate with plumbing engineer.

9.3. Existing Roofs

In addition to the criteria above, identify the following special criteria for existing roofs.

- Existing Roofing Systems: Identify existing roof materials and assemblies. Assist Owner to have test cuts done by a roofer to verify actual conditions. Investigate typical field conditions, typical edge conditions and typical details. Identify roofing manufacturer if possible.
- Existing Roof Condition: Describe condition of existing roofs, roof mounted equipment and roof accessories. Describe condition of adjacent walls, parapets, copings, flashings and other construction which may affect roof membrane
- Existing Slope and Drainage: Identify the slope of the existing roof and drainage patterns. Note any Ponding. Assist Owner in obtaining a reliable "topographic" survey of the existing roof. Measurements may be needed both above and below the roof to verify the use of tapered insulation.
- Existing Secondary Drainage: Identify how secondary or overflow drainage is accommodated. Identify elevation of secondary drains in relation to main drains and roof perimeter.
- Roof Survey: Assist Owner in obtaining a survey of the roof by a qualified consultant to determine moisture content of roofing materials, insulation and substrate. Infrared scans and nuclear

samplings are two common methods.

- Existing Roof Warranties: Identify any existing roof warranties.
- Existing Roof Shape and Complexity: What is relative complexity of the roof shape and the number of penetrations (i.e., wide open and flat or encumbered up with rooftop equipment). Identify any large openings in the existing building, large overhangs, or other conditions that may add to the roof uplift load by adding a positive pressure from below.
- Re-roofing Code Requirements: Identify code requirements for re-roofing: minimum slope for various materials, requirements for removal of existing roofs. Include requirements from each applicable code and select most stringent.
- Hazardous Materials: Has Owner tested for presence of hazardous materials in the existing assembly? Old roofs commonly contain asbestos in various asphaltic mastics, cements and coatings.
- Drains and Scuppers: What are the criteria for sizing of drains.

10. Exterior Wall Systems

10.1. Exterior Wall Standards

Edit the following list and add other standards as required to suit the project.

- PCI Precast Concrete Institute.
- NCMA National Concrete Masonry Association
- BIA Brick Institute of America
- SMACNA Architectural Sheet Metal Manual.
- EIMA EIFS Industry Members Association
- MIA Marble Institute of America (retain for all exterior stone).
- Indiana Limestone (retain only for limestone from Indiana).
- NBGQA National Building Granite Quarries Association
- CSI Cast Stone Institute.
- SWRI Sealant and Waterproofing Research Institute.

10.2. Exterior Wall Criteria

Identify criteria for system.

- ✓ Owner's Preference for materials or systems: *Identify Owner's preferences based on past experience, campus or corporate standards, etc.*

- Required Reliability: Identify required reliability. Must wall remain intact after a seismic event? Are walls subject to damage or abuse from pedestrians or vehicles? Are walls subject to graffiti?
- Air Leakage Criteria: Identify air leakage criteria with the mechanical engineer.
- Water Leakage Criteria: Identify Owners tolerance to leaks in relationship to cost. For example, most owners of warehouses will tolerate a small amount of leaks in exchange for cost savings from single thickness masonry walls. Museums will not tolerate any leaks. Review carefully with the Owner, it is very easy for them to say they will tolerate absolutely no water intrusion at any point which may force a walls system more expensive than necessary. Small leaks in truck docks, mechanical rooms, penthouses, and similar service spaces are routinely tolerated by most building owners.
- Thermal Performance Criteria: Refer to section above.
- Fire Resistance: Identify required fire rating of exterior walls
    - Exterior Wall rating:
    - Type of exterior wall assembly: *Identify specific wall assembly required per code, such as Firewall" or "Fire Separation Assembly".*
    - Maximum percentage of openings allowed.
    - Opening protection
- Acoustical Performance: Identify requirements for exterior walls to control the passage of sound, either from exterior in or from interior out. Note that both building and zoning codes may have requirements for control of sound.
- Vapor Control: Identify the requirements for control of the transmission of vapor-laden air. Identify if project is located in a primarily cold climate with a vapor drive primarily from the interior to the exterior, a primarily hot climate with a vapor drive primarily from the exterior to the interior or a middle climate where the direction of the vapor drive varies with the season.
- Security: Identify criteria for exterior walls related to the security design for the project. Indicate required resistance to

physical assault, bullets, bomb blast, or other threats.

10.3. Existing Exterior Wall Systems

In addition to the criteria above, identify the following criteria for existing walls.

- Existing Wall Systems: Identify existing materials and assemblies. Assist Owner to have exploratory cuts done by a contractor to verify actual conditions. Identify material or system manufacturer if possible.
- Existing Wall Condition: Describe condition of existing wall systems and accessories. Describe condition of adjacent roofs, canopies, parapets, copings, flashings and other construction that may affect wall system.
- Existing Warranties: Identify any existing warranties on wall systems.
- Code Requirements: Identify code requirements for improving or replacing existing exterior walls as part of a larger renovation. Include requirements from each applicable code and select most stringent.
- Hazardous Materials: Has Owner tested for presence of hazardous materials in the existing assembly? Asbestos is commonly found in old cementitious panels, some types of insulation, spray-on fireproofing, fire stopping and various other materials.

Note: if project includes a curtainwall only, the paragraphs above may be deleted and only the curtainwall portion of the section below need be retained

11. Exterior Windows, Curtainwall and Storefront Systems

11.1. Exterior Window, Curtainwall, and Storefront Standards

Edit the following list and add other standards as required to suit the project. Add standards for stone or other products if included in the curtainwall:

- AAMA American Architectural Manufacturers Association
- SMACNA Architectural Sheet Metal Manual.

- GANA Glass Association of North America
- IGMA Insulating Glass Manufacturers Alliance

11.2. Exterior Window, Curtainwall or Storefront Criteria

Identify criteria for system.

- Owner's Preference for materials or systems: Identify Owner's preferences based on past experience, campus or corporate standards, etc.
- Required Reliability: Identify required reliability. Must wall remain intact after a seismic event? Are walls subject to damage or abuse from pedestrians or vehicles? Are walls subject to graffiti?
- Air Leakage Criteria: Maximum 0.06 CFM/square foot at [1.57] [6.24] [10] [12] [15] psf as measured by ASTM E283 under laboratory conditions. *For most projects select 6.24 or 10 psf. For buildings up to 15 stories 12 psf will be adequate. Use 15 for high rise or coastal. Use 1.57 only for very budget driven projects. Coordinate air leakage criteria with the mechanical engineer.*
- Water Leakage Criteria: *See criteria above for values.*
    - No uncontrolled leaks at a static pressure of [1.57] [6.24] [10] [12] [15] psf as measured by ASTM ???? under laboratory conditions.
    - No uncontrolled leaks under dynamic loading under AAMA 501.1 under laboratory conditions.
- Thermal Performance Criteria: Refer to section above.
- Fire Resistance: *Identify required fire rating of exterior wall assemblies (curtainwall) and for openings in exterior walls. Indicate maximum percentage of openings to wall area for each level of fire protection.*
- Acoustical Performance: *Identify requirements for exterior windows, curtainwall and storefront to control the passage of sound, either from exterior in or from interior out. Note that both building and zoning codes may have requirements for control of sound.*
- Condensation Control: Values measured per AAMA 1503.1 under laboratory conditions. *Identify the requirements for control of the condensation. Determine required minimum CRF values with the mechanical engineers. Note that CRF values*

published by most manufacturers are averages of multiple temperature readings. The test procedure places no limits on the maximum deviation from the published average.

  - Minimum CRF for Frame:
  - Minimum CRF at Edge of Glass:
  - Minimum CRF at Center of Glass:

- Glare Control: Identify the requirements for control of glare, especially at spaces that require use of computers and other video devices..
- Security: Identify criteria for exterior windows, curtainwall and storefront related to the security design for the project. Indicate required resistance to physical assault, bullets, bomb blast, or other threats. Note that it is becoming increasingly common for Owners to require some form of security glazing at the ground floor as a minimum.

11.3. Existing Exterior Window, Curtainwall, or Storefront Systems

In addition to the criteria above, identify the following criteria for existing windows, curtainwall and storefront.

- Existing Systems: Identify existing materials and assemblies. Assist Owner to have exploratory cuts done by a contractor to verify actual conditions, especially at the interface of the window, curtainwall or storefront system. Identify material or system manufacturer if possible. Identify existing glass and glazing if possible.
- Existing Condition: Describe condition of existing window, curtainwall and storefront systems and accessories. Describe condition of adjacent walls, flashings and other construction, which may affect system.
- Existing Warranties: Identify any existing warranties.
- Code Requirements: Identify code requirements for improving or replacing existing windows, curtainwall or storefront as part of a larger renovation. Include requirements from each applicable code and select most stringent.

12. Skylight Systems

12.1. Skylight Standards

Edit the following list and add other standards as required to suit the project. Alter the section to suit glass canopies.

- AAMA Sloped Glazing Manual
- GANA Glazing Association of North America
- IGMA Insulating Glass Manufacturers Alliance
- SWRI Sealant and Waterproofing Research Institute.

12.2. Skylight Criteria

Identify criteria for system

- Owner's Preference for materials or systems: Identify Owner's preferences based on past experience, campus or corporate standards, etc.
- Required Reliability: Identify required reliability. Must skylight remain intact after a seismic event?
- Air Leakage Criteria: Maximum 0.06 CFM/square foot at [1.57] [6.24] [10] [12] [15] psf as measured by ASTM E283 under laboratory conditions. For most projects select 6.24 or 10 psf. For buildings up to 15 stories 12 psf will be adequate. Use 15 for high-rise or coastal. Use 1.57 only for very budget driven projects. Coordinate air leakage criteria with the mechanical engineer.
- Water Leakage Criteria: See criteria above for values.
    - No uncontrolled leaks at a static pressure of [1.57] [6.24] [10] [12] [15] psf as measured by ASTM ???? under laboratory conditions.
    - No uncontrolled leaks under dynamic loading under AAMA 501.1 under laboratory conditions.
- Thermal Performance Criteria: Refer to section above.
- Acoustical Performance: *Identify requirements for skylight to control the passage of sound, either from exterior in or from interior out. Note that both building and zoning codes may have requirements for control of sound.*
- Condensation Control: Values measured per AAMA 1503.1 under laboratory conditions. *Identify the requirements for control of the condensation. Determine required minimum CRF values with the mechanical engineers.*
    - Minimum CRF for Frame:

- Minimum CRF at Edge of Glass:
- Minimum CRF at Center of Glass:

- Smoke Control: Identify the requirements for use of operable skylights as part of a smoke control system.
- Glare Control: Identify the requirements for control of glare, especially at spaces that require use of computers and other video devices. Note that even relatively small areas of skylight can create glare problems if not properly designed.
- Security/Fall Protection: Identify criteria for skylights related to the security design for the project. Indicate required resistance to physical assault, bullets, bomb blast, or other threats. Note that it is not uncommon for skylights in warehouses to require burglar bars to stop intrusion from roof. Identify requirements for fall protection at skylights in the event that the glazing fails. This particularly applies to plastic bubble type skylights.

13. Exterior Doors

13.1. Exterior Door Standards

Edit the following list and add other standards as required to suit the project.

- HMMA Hollow Metal Manufacturers Association

HMMA is a higher standard and allows more customization. Retain SDI for less customized and smaller projects. Do not retain both

- SDI Steel Door Institute
- WDMA Window and Door Manufacturers Association
- BHMA Builders Hardware Manufacturers Association
- AAMA American Architectural Manufacturers Association
- GANA Glass Association of North America
- IGMA Insulating Glass Manufacturers Alliance
- SWRI Sealant and Waterproofing Research Institute.

13.2. Exterior Door Criteria

Identify criteria for system.

- Owner's Preference for materials or systems: Identify Owner's preferences based on past experience, campus or corporate standards, etc.
- Required Durability and Reliability: Identify required durability and reliability based on frequency and type of use. Emergency egress doors from stair towers see much less use than the main entrance to an office building. Schools see much harder abuse than an office building.
- Air Leakage Criteria for Aluminum Entrance Doors only: Maximum 0.06 CFM/square foot at [1.57] [6.24] [10] [12] [15] psf as measured by ASTM E283 under laboratory conditions: For most projects select 6.24 or 10 psf. For buildings up to 15 stories 12 psf will be adequate. Use 15 for high-rise or coastal. Use 1.57 only for very budget driven projects. Coordinate air leakage criteria with the mechanical engineer. Note that typically only doors that are part of an aluminum storefront system have tested leakage criteria. Delete this paragraph for other types of doors.

- Water Leakage Criteria: Identify specific water leakage criteria for systems under laboratory test conditions for doors in curtainwall or storefront. Identify Owners real world tolerance to leaks in relationship to cost. For example, most owners will tolerate a small amount of leakage under a door into a roof top stair tower or at the entrance to a parking garage elevator lobby. Review carefully with the Owner, it is very easy for them to say they will tolerate absolutely no water intrusion at any point which may force a solution more expensive than necessary. Overhangs, canopies and vestibules may be required to meet a criteria of absolutely no leaks when simply putting down mats on rainy days will suffice.
- Structural Criteria: Identify the loading criteria for the exterior doors from the Structural SOC.
- Thermal Performance Criteria: Refer to Enclosure Criteria section above.
- Fire Resistance: Identify required fire rating of exterior doors. Indicate maximum percentage of openings to wall area for each level of fire protection. Coordinate total area with other openings.
- Acoustical Performance: Identify requirements for exterior doors to control the passage of sound, either from exterior in or from interior out. Note that both building and zoning codes may have requirements for control of sound.
- Security: Identify criteria for exterior doors related to the security design for the project. Indicate required resistance to physical assault, bullets, bomb blast, or other threats.
- Safety Glazing: Identify requirements for safety glazing at doors and sidelights.
- Accessibility: Identify requirements for accessibility at main entrances, secondary entrances, and doors used only for service access. Identify the maximum opening force if required.
- Size: Identify requirements for size of openings related to passage of furniture, fixtures and equipment, especially, oversized doors required for long term maintenance of mechanical and electrical equipment.

13.3. Existing Exterior Doors

In addition to the criteria above, identify the following criteria for existing doors.

- Existing Systems: Identify existing materials and assemblies. Assist Owner to have exploratory cuts done by a contractor to verify actual conditions, especially at the interface of the doors with adjacent construction. Identify material or system manufacturer if possible. Identify existing glass and glazing if possible.
- Existing Condition: Describe condition of existing doors, hardware and accessories. Describe condition of adjacent walls, flashings and other construction that may affect system. Describe drainage at threshold and adjacent paving.
- Existing Warranties: Identify any existing warranties.
- Code Requirements: Identify code requirements for improving or replacing existing doors as part of a larger renovation. Include requirements from each applicable code and select most stringent. Main entrances frequently require upgrading for accessibility during renovations of other parts of the building.
- Hardware: Identify existing hardware. Include material, name brands, function, labels, keying and condition.

13.4. Door Hardware

Identify criteria important for the owner to understand here. Use the Architectural Roofing Criteria Worksheet to develop final and complete criteria required for Kling documentation.

- Owner's Preference for materials or systems: Identify Owner's preferences based on past experience, campus or corporate standards, etc.
- Required Durability and Reliability: Identify required durability and reliability based on frequency and type of use. Emergency egress doors from stair towers see much less use than the main entrance to an office building. Schools see much harder abuse than an office building.
- Security: Identify criteria for exterior door hardware related to the security design for the project. Indicate required resistance to physical assault, bullets, bomb blast, or other threats.
- Keying: Identify the Owners requirements for keying systems.

14. Below Grade Wall and Horizontal Systems

14.1. Below-Grade System

Edit the following list and add other standards as required to suit the

Standards *project.*

- NRCA Roofing and Waterproofing Manual.
- NCMA National Concrete Masonry Association
- SMACNA Architectural Sheet Metal Manual.
- SWRI Sealant and Waterproofing Research Institute.

14.2. Exterior Below-Grade System Criteria

Identify criteria for system.

- Typically all enclosed space below grade (except below slabs-on-grade) be protected with a waterproofing system, regardless of the water table.
- Owner's Preference for materials or systems: *Identify Owner's preferences based on past experience, campus or corporate standards, etc.*
- Required Reliability: *Identify required reliability. Will below grade plazas or other construction making future access difficult cover systems? What is the function of the enclosed space and the value of the contents?*
- Water Leakage Criteria: *Identify Owners tolerance to leaks in relationship to cost.*
- Thermal Performance Criteria: Refer to Enclosure Criteria section above.
- Construction Schedule: *Review construction schedule and sequencing with Owner and CM. Some waterproofing systems are more tolerant of moisture from curing concrete than others.*

15. Slabs-on-Grade

Identify criteria important for the owner to understand here. Use the Architectural Roofing Criteria Worksheet to develop final and complete criteria required for Kling documentation.

15.1. Criteria

Identify criteria for system.

- Flatness: Identify criteria for flatness of slabs-on-grade as required for intended use.
- Waterproofing: Determine if waterproofing is required based on geotechnical survey. Coordinate requirements for waterproofing with the structural engineer.

- Required Reliability: Identify required reliability. Will below slab systems be covered by functions making future access difficult?. What is the slab finish, function of the enclosed space and the value of the contents?
- Water Leakage Criteria: Identify Owners tolerance to leaks in relationship to cost.

- Vapor Control: Identify criteria for need of control of vapor based on interior function and finish. Typically a vapor retarder below slabs on grade is good practice unless no finish is required or foreseeable.
  - Sand Blotter: The use of a sand blotter layer over the vapor barrier may be needed to reduce slab curl. However, blotters can cause moisture problems that the vapor retarder is meant to eliminate, so their use must be carefully evaluated. Coordinate with the structural engineer and the Owner. See ACI data on determining use of sand blotter.
- Thermal Performance Criteria: Refer to Enclosure Criteria section above.
- Construction Schedule: *Review construction schedule and sequencing with Owner and CM. Some waterproofing systems are more tolerant of moisture from curing concrete than others.*

16. Miscellaneous Exterior Criteria

16.1. Expansion Joints

Identify the criteria for the placement of expansion joints.

17. Interior Construction Criteria

Describe needed partitions, doors, shafts and ceilings. Describe required finishes by space categories. Stress durability and maintenance.

17.1. Window Treatment

Describe Owner's preference for window treatment. Include treatment of borrow lights and sidelights. Identify special glare control issues and areas requiring blackout shades. Identify any special filtering or protection.

18. Accessibility

Describe need for accessibility within the building for compliance with American with Disabilities Act Accessibility Guidelines (ADAAG), ANSI A 117.1, appropriate portions of the building code, and any other applicable regulations. Clearly identify strict code requirements versus ADA Guidelines.

18.1. Extent

Describe the extent of program spaces required to be accessible, specifically list spaces that may be adapted to be accessible in the future and which spaces are not required to be accessible. Explain interpretation, citing appropriate regulations.

18.2. Egress

Describe accessibility requirements for egress. Separate strict code criteria from ADA Guidelines. Note that most building codes have separate requirements for accessible egress, which are particularly important on multi-story buildings. Coordinate with Life Safety section and requirements for elevator. Coordinate emergency power requirements for accessible elevators with the Electrical section.

18.3. Remodeling / Renovation of Existing Facilities

Describe code and guideline requirements for accessibility on remodelings, renovations, retrofits, changes of use, additions, and other alterations to existing buildings. Coordinate with the Life Safety section.

Federal Codes and Regulations: ADAAG

State Codes and Regulations:

Local Codes and Regulations:

18.4. Special Use Exemptions

Record any special interpretations or variances that Owner may have obtained for special use of facilities that are exempt from accessibility requirements. ADA and most other accessibility regulations allow for exemptions when the space is used for a function that cannot be performed by an impaired or disabled person. Obtain documentation from Owner.

19. Acoustical Criteria

19.1. Off-site Noise Sources

Describe noise generated off the site that needs to be controlled, i.e. facilities next to airports or busy highways.

19.2. Control of Noise Generated by the Facility

Describe requirements for control of noise generated on the site and attenuation of the noise at property lines. Check zoning codes and regulations.

19.3. Background Noise Levels

Describe Owner's requirements for acceptable background noise levels for each type of space. Use descriptions below to help owner understand and equate to NC numbers listed in mechanical OPR.

20. Other Criteria

20.1. Radio Frequency Interference or Electromagnetic Interference (RFI/EMI) Shielding	Identify requirements for shielding from radio frequency interference and/or electromagnetic interference. Describe specific areas where shielding is required if not required for entire building.
20.1.1. Computer Rooms, Teledata/Closets	Note that it is not uncommon for some users to request RFI/EMI shielding of major teledata or computer rooms. If shielding is required cross-reference to all affected sections of the OPR. At a minimum, desktop computers may need to be kept a certain small distance (3 – 5 feet) from rooms with electrical transformers and other electrical equipment.
20.2. Lightning Protection	Describe needed rooftop lightning protection system. Coordinate with electrical.
20.3. Odors	Describe any special requirements for control of noxious odors.
20.3.1. Offsite Odors	Describe criteria for control of noxious odors that are generated off site that affect the project.
20.3.2. Control of Odors Generated by Facility	Describe criteria for control of any noxious odors generated on the site. Consider mechanical exhaust, and odor that may be generated by trash areas. In some areas it may be necessary to provide a refrigerated room to store garbage.

Annex K: Basis of Design (BOD) for the Building's Exterior Enclosure

Commentary: This annex is intended to provide information and examples about the structure and contents of the Basis of Design as they apply to the building's exterior enclosure.

This annex contains one sub-annex: An example checklist of contents of the BOD for the building exterior enclosure.

This is the type of product used in practice by firms that place high priority on commissioning activities for the exterior enclosure.

Credits: The example checklist in Annex K.1 has been provided by David Altenhofen.

ANNEX K.1: Checklist for Architecture Basis of Design (BOD)

1. Building Description

Describe the building design and how it fulfills the goals and objectives listed in the OPR.

2. Site Design

Describe the relationship of the site design with the building design. Coordinate with Site/Civil.

2.1. Neighborhood / Context

Describe how the design addresses the neighborhood and context.

2.2. Existing Buildings

Describe how the design responds to existing buildings.

2.3. Master Plan

Describe how the design responds to master planning issues.

2.4. Circulation / Access

Describe the design accommodates circulation and access.

Major Building Access:

Secondary Building Access:

Deliveries and Services:

- ✓ Trash Docks and Compactors.
- ✓ Kitchen, Cafeteria or other food service Deliveries and Services.
- ✓ Lab, Animal, GMP or other special Deliveries and Services.
- ✓ Ambulance or Emergency Service.

2.5. Zoning

Compare actual versus allowable building footprint, maximum height, FAR, and other zoning issues. Coordinate with the Site/Civil Section.

Buildable Dimensions and Area:

- ✓ Actual:
- ✓ Allowable:

Maximum FAR:

- ✓ Actual:

- ✓ Allowable:

Maximum Height:

- ✓ Actual:
- ✓ Allowable:

Upper Level Setbacks:

- ✓ Actual:
- ✓ Allowable:

2.5.1.	Zoning or Planned Unit Development Restrictions on Materials or Design	Describe response to special restrictions on the design..
2.5.2.	Local, Neighborhood or Community Review Boards or Approvals	Describe obtained or pending approvals from Review Boards. If approvals are pending, describe remaining process, schedule and risks of moving forward without approval.

3. Sustainability

Describe the design concepts and features for sustainability. Indicate compliance with criteria such as LEED ratings or ASHRAE 90.1. Coordinate with section below for envelope criteria.

3.1. Energy Conservation

3.2. Life Cycle Costing

3.3. Recycled Materials

4. Existing Facilities

Describe compliance with special requirements for renovations, restorations, additions, alterations or any other work on an existing facility. Coordinate this overall section with the “Existing” paragraphs in the remainder of the BOD. Coordinate with the code analysis and life safety section.

5. Program

5.1. Functional Criteria

Describe how the facility fulfills the requirements of the program..

5.2. Program Scope

Tabulate actual Net and Gross Areas and compare against program areas..

5.3. Flow Analysis

Describe flow of incoming and outgoing materials, clean and dirty personnel, animals, waste, process materials, etc. Attach Flow Diagrams in Appendix.

5.4. Special Features

Describe any special features required for fulfillment of the program, i.e. airlocks, vestibules, interstitial spaces, service zones, or mechanical spaces.

6. Exterior Envelope Thermal Performance

Describe compliance with criteria for the thermal performance of the exterior envelope.

Describe the method of analysis used.

Coordinate this section carefully with the Mechanical Engineers and with other paragraphs below describing the exterior systems.

6.1. Alternate Compliance

Describe alternate analysis methodology if used, to verify compliance.

6.1.1. Envelope Method

6.1.2. Total Building Method

7. Roofing

7.1. Roof System Descriptions

Complete each of the System Descriptions Below. Delete portions of the assembly not required. Each system must meet the requirements liste*d in the OPR.*

7.1.1. Roofing System Option A

- Substrate:
- Underlayment:
- Vapor Retarder
- Insulation
- Insulation Cover Board

- Roof Membrane
- Base Flashing
- Special Comments:
- Fire Rating:
- U-Value
- Reflectivity:

7.1.2. Roofing System Option B

- Substrate:
- Underlayment:
- Vapor Retarder
- Insulation
- Insulation Cover Board
- Roof Membrane
- Base Flashing
- Special Comments:
- Fire Rating:
- U-Value
- Reflectivity:

7.1.3. Roofing System Option C

- Substrate
- Underlayment:
- Vapor Retarder
- Insulation
- Insulation Cover Board
- Roof Membrane
- Base Flashing
- Special Comments:
- Fire Rating
- U-Value
- Reflectivity:

7.1.4. Special Construction

- Expansion Joints and Roof Dividers: Describe how expansion joints and roof dividers will be constructed for each system.

- Drain Sizing: Calculate size of drains, gutters, overflows and scuppers. See SMACNA and plumbing codes. Coordinate with plumbing engineer. Describe differences between systems if relevant.

7.2. Roof System Comparison Table

Complete the comparison table below for each type of roof system. Criteria listed is generic. Customize criteria to suit project based on OPR. Add criteria for Re-roofing and Roofing of Existing Buildings.

	Roof System Type A	Roof System Type B	Roof System Type C
Complies with Owner's Standards			
Complies with Owner's Insurance Requirements			
Warranty			
Anticipated Lifespan			
Robustness – strong, able to withstand abuse			
Withstand Chemical Attack			
Redundant – multiple layers in field and flashing			
Quality control of contractors by manufacturer			
Ease of installing membrane			
Ease of seaming			
Flashing constructability			
Flashing reliability			
Thermal bridging and back-out of mechanical fasteners			
Ease of finding leaks			
Ease of repairing leaks or making alterations			

Dead-level roofs acceptable

Quality of vapor retarder (if required)

Insulation and V.R. attachment (hot asphalt) contributes to water-tightness

Two-stage installation possible to allow for construction traffic

Manufacturers are quality driven or commodity driven

Relative costs

Life Cycle Costs

Thickness (mils)

Application is environmental acceptable to Owner

Application is acceptable to Owner's safety program

Cold weather installation

Drilled anchors required for concrete substrates

Project Specific Items

a.

b.

c.

7.3. Recommended System

Discuss the important strengths and weaknesses of the systems per the comparison above. Indicate recommended system and the Owner's decision if different.

8. Exterior Wall Systems

8.1. Wall System Descriptions

Complete each of the System Descriptions Below. Each system must meet the requirements listed in the OPR. If the building design requires more than one type of wall assembly, (ie. Brick and metal panel) then include options and selection analysis for each type.

8.1.1. Wall System Option A

8.1.2. Wall System Option B

8.1.3. Wall System Option C

8.2. Wall System Comparison Table

Complete the comparison table below for each type of wall system. Criteria listed is generic. Customize criteria to suit project based on OPR. Add criteria for walls on Existing Buildings.

	Option A	Option B	Option C
Complies with Owner's Standards or Preference:			
Reliability:			
Robustness:			
Redundancy:			
Ease of Installation:			
Impact on Schedule:			
Impact on Sequencing:			
Ease of Repair:			
Sustainable Design:			
Air Leakage:			
Water Leakage			
Structural Criteria:			
Thermal Performance:			
Fire Resistance:			

Acoustical Performance:

Quality of Vapor Control:

Manufacturers Capabilities

Manufacturer's Quality Control Program:

Warranty:

Initial Relative Cost:

Life Cycle Cost:

Project Specific Items:

8.3. Recommended System

Discuss the important strengths and weaknesses of the systems per the comparison above. Indicate recommended system and the Owner's decision if different

Note: if project includes a curtainwall only, the paragraphs above may be deleted and only the curtainwall portion of the section below need be retained

9. Exterior Windows, Curtainwall and Storefront Systems

9.1. Exterior Window, Curtainwall or Storefront Systems

Describe systems. If appropriate, (i.e. large and complex areas of curtainwall, comparison of stick-built versus unitized) describe options and selection analysis. Each system must meet the requirements listed in the OPR or discuss reasons to vary from OPR. If the building design requires more than one type of window, curtainwall or storefront assembly, describe each. Describe work for existing windows, curtainwalls and storefronts if required. Include the following topics as appropriate:

Industry standards (i.e. AAMA class rating for windows)

Framing materials and finish:

Glass and Glazing methods:

Shadow boxes and spandrel:

Installation Methods and Anchorage to structure or substrate:

Accessories and Trim (i.e. sunshades, extended mullion covers, column covers, blind pockets, sill extensions, radiation enclosures).

Owner's Preference for materials or systems:

Reliability:

Air Leakage:

Water Leakage:

Structural Criteria:

Thermal Performance:

Fire Resistance:

Acoustical Performance

Condensation Control:

Glare Control:

Security:

10. Skylight Systems

10.1. Skylights

Describe systems. If appropriate, (i.e. large and complex areas of skylight, comparison of skin systems over structural steel versus self-supporting) describe options and selection analysis. Each system must meet the requirements listed in the OPR or discuss reasons to vary from OPR. If the building design requires more than one type of skylight, describe each. Describe work for existing skylights if required. Include the following topics as appropriate:

System type (i.e. four-sided structural silicone glazed, two-sided structural silicone glazed with external covers at vertical mullions)

Framing materials and finish:

Glass and Glazing methods: *Note that glass skylights should always have an external wet seal.*

Shadow boxes, spandrel or insulated metal panels:

Installation Methods and Anchorage to structure or substrate:

Accessories and Trim (i.e. sunshades, sill extensions, radiation enclosures).

Owner's Preference:

Reliability:

Air Leakage:

Water Leakage:

Structural Criteria.

Thermal Performance: Refer to Envelope section above.

Acoustical Performance:

Condensation Control:

Smoke Control:

Glare Control:

Security/Fall Protection:

NOTE: IF EXTERIOR DOORS ARE PART OF A CURTAINWALL OR STOREFRONT THEN THE PARAGRAPHS BELOW MAY BE INCORPORATED INTO SECTION ABOVE.

11. Exterior Doors

11.1. Exterior Doors

Describe doors. If appropriate, (i.e. heavy traffic doors) describe options and selection analysis. Each door must meet the requirements listed in the OPR or discuss reasons to vary from OPR. If the building design requires more than one type of door, describe each. Describe work for existing doors if required. Include the following topics as appropriate:

System type (i.e. HMMA commercial, heavy commercial, security)

Materials and finish:

Glass and Glazing methods: Identify safety glazing.

Installation Methods and Anchorage to structure or substrate:

Accessories and Trim:

Owner's Preference:

Durability and Reliability:

Air Leakage

Water Leakage:

Thermal Performance: Refer to Envelope section above.

Fire Resistance:

Acoustical Performance:

Security:

Accessibility:

11.2. Door Hardware

Describe door hardware for each typical exterior door. If appropriate, (i.e. heavy traffic doors) describe options and selection analysis. Each system must meet the requirements listed in the OPR or discuss reasons to vary from OPR. Describe work for existing doors if required. Include the following topics as appropriate:

Accessibility:

Hanging Devices:

Operators and Closers:

Locking Devices:

Thresholds:

Owner's Preference for materials or systems:

Durability and Reliability:

Security:

Keying:

Weather-stripping:

12. Below Grade Wall and Horizontal Systems

12.1. Exterior Below-Grade Systems

Describe below-grade systems. If appropriate, (i.e. crucial projects, large areas of horizontal waterproofing) describe options and selection analysis. Each system must meet the requirements listed in the OPR or discuss reasons to vary from OPR. If the building design requires more than one type of below grade system (i.e. foundation walls, horizontal systems and pits), describe each. Describe work for existing below grade systems if required. Include the following topics as appropriate:

Materials and Systems. Include substrate, waterproofing, protection, insulation, drainage matting, geotextiles, subsurface drainage, etc.

Installation Methods:

Owner's Preference

Reliability:

Water Leakage:

Thermal Performance: Refer to Envelope section above.

Construction Schedule and Sequencing:

Warranty:

13. Slabs-on-Grade

13.1. Concrete Slabs-on-Grade

Describe slab-on-grade systems. If appropriate, describe options and selection analysis. Each system must meet the requirements listed in the OPR or discuss reasons to vary from OPR. If the building design requires more than one type of slab-on-grade system, describe each. Describe work for existing slabs-on-grade systems if required. Include the following topics as appropriate:

Materials and Installation:

Flatness:

Waterproofing:

Vapor Control: Is a sand blotter required.

Thermal Performance: Refer to Envelope section above.

Construction Schedule:

14. Miscellaneous Exterior Criteria

14.1. Expansion Joints

Describe expansion joint systems, starting at foundation, extending up building, across plazas and roofs and down to foundation again. If appropriate, describe options and selection analysis. Each system must meet the requirements listed in the OPR or discuss reasons to vary from OPR. If the building design requires more than one type of expansion joint system, describe each. Describe work for existing expansion joint systems if required.

15. Interior Finishes

16. Accessibility

Identify compliance with accessibility criteria.

16.1. Extent

16.2. Egress

16.3. Remodeling / Renovation of Existing Facilities

17. Acoustical

17.1. Off-site Noise Sources

Identify the measures taken to control noise generated off-site. Indicate compliance with criteria.

17.2. Control of Noise Generated by the Facility

Identify the measures taken to control noise generated on-site. Identify compliance with zoning codes and regulations.

17.3. Internal Acoustic Isolation

Identify the measures to be taken for acoustic isolation for each type of space requiring control. Include physical isolation (partitions, doors, windows, borrow-lights, electrical boxes and other penetrations), masking, absorption or other methods.

Conference Rooms:

Executive Offices:

Typical Offices:

Laboratories:

Mechanical Rooms:

Main Electrical Rooms:.

Electrical Distribution Closets:

Teledata Closets:

17.4. Background Noise Levels

Identify methods to maintain maximum acceptable background noise levels for each type of space. Include absorption, masking, control of mechanical systems, etc.

Conference Rooms:

Training Rooms:

Executive Offices:

Typical Offices:

Open Office Spaces:

Cafeterias:

Laboratories:

17.5. Special Space Acoustic Criteria	Identify measures taken to satisfy special acoustic criteria, i.e. teleconferencing facilities, auditoriums, sound proof rooms.

18. Other Criteria

18.1. Radio Frequency Interference or Electromagnetic Interference (RFI/EMI)	Identify methods and locations of shielding in response to OPR.
18.1.1. Computer Rooms, Teledata/Closets	Identify measures taken to comply with criteria..
18.2. Lightning Protection	Describe needed rooftop lightning protection system. Coordinate with electrical.
18.3. Odors	Identify measures for control of noxious odors.
18.3.1. Offsite Odors	Identify measures to control noxious odors that are generated off site.
18.3.2. Control of Odors Generated by Facility	Identify measures to control of any noxious odors generated on the site.
18.4. Signage	Identify extent and design of signage or identify if signage.

Annex L: Specifications

Commentary: This annex is intended to provide available information and examples about specifications related to the design, construction, maintenance, and commissioning of the building exterior enclosure.

There are 4 sub-annexes that together provide several perspectives on relevant specifications.

- L.1 - Preliminary Table of Contents of Sections That May Include Facility Exterior Envelope Commissioning Requirements
- L.2 - Masterspec Facility Exterior Enclosure Commissioning 019115
- L.3 - Example Draft Specification, Section 01811 - Building Exterior Enclosure Commissioning
- L.4 – Example Specification 01810 of General Requirements for a Recent Project
- L.5 – Example Specification 01811 of Fenestration System Testing Requirements for a Recent Project

Credits: The following persons and organizations have provided materials for this annex and its sub-annexes:

- Sub-annexes L.1 and L.2 have been provided by Paul Brosnahan of Arcom.
- Sub-annex L.3, the example draft specification for the exterior enclosure, has been provided by Wiss, Janney, Elstner Associates, Inc. (WJEA).
- Sub-annexes L.4, example general requirements specification 01810, and L.5, Example Specification 01811 of Fenestration System Testing Requirements, have been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

Annex L.1: Preliminary Table of Contents of Sections That May Include Facility Exterior Envelope Commissioning Requirements

Annex L.2:
Masterspec Facility Exterior Enclosure Commissioning 019115

SECTION 019115 – FACILITY EXTERIOR ENCLOSURE COMMISSIONING

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this Section.

Documents referenced in paragraph below should be created during schematic design phase or earlier and updated as design progresses. They may be provided to the Contractor when the commissioning process is implemented on the Project.

B. Owner's Project Requirements and Basis of Design documentation are included for information only.

1.2 SUMMARY

A. This Section includes exterior enclosure commissioning procedures, including substructure, superstructure, exterior enclosure, and roofing construction that protects climate-controlled interior spaces from unconditioned spaces and the exterior environment, as follows:

1. Below-grade construction including foundations, basements, and slab-on-grade that functions as part of the exterior enclosure system but excluding structural systems and components.
2. Superstructure floor and roof construction that functions as part of the exterior enclosure system.
3. Exterior enclosure construction, above grade, including exterior opaque walls, windows, and doors including sheathing, framing, and insulation, and interior finish materials attached to the exterior wall.
4. Roofing, including roofing system, roofing insulation, and skylights, hatches, and other roof openings.

B. Related Sections:

1. Division 01 Section "General Commissioning Requirements" for general requirements for commissioning including definitions, commissioning team membership, Owner's responsibilities, Contractor's responsibilities, and Commissioning Authority's responsibilities.
2. Division 03 through 14 Sections for facility exterior enclosure commissioning requirements specific to the Work of each Section.

1.3 ALLOWANCES

Retain this Article if commissioning testing and inspections are paid for by Contractor under an allowance. Do not include amounts in this Section.

A. Commissioning testing and inspection costs are included in the Commissioning Testing Allowance in Division 01 Section "Allowances" Division 1 Section "Allowances"

1.4 UNIT PRICES

Retain this article if commissioning testing is paid for by Contractor by an allowance and the allowance can be adjusted to cover actual time required. Do not include amounts in this Section.

A. Commissioning Testing Allowance may be adjusted up or down by the "Commissioning Testing Man-Hour" unit prices in Division 01 Section "Unit Prices" when actual man hours are computed at the end of commissioning testing.

1.5 CONTRACTOR'S RESPONSIBILITIES

Retain option in first paragraph below if Contractor is engaged during or before the design phase.

A. Attend [**design- and**]construction-phase coordination meetings.

B. Provide schedule of field quality control tests and inspections required by the Contract Documents to Commissioning Authority.

1. Update schedule [**weekly**] [**biweekly**] [**monthly**] <**Insert frequency**>throughout the construction period.

C. Submit field quality control testing and inspection reports on exterior enclosure construction to the Commissioning Authority.

D. Submit operation and maintenance data for systems, subsystems, and components to the Commissioning Authority.

E. Participate in testing-procedures meetings.

F. Participate in testing of installed systems, subsystems, and construction.

G. Provide test data, inspection reports, and certificates to Commissioning Authority.

H. Participate in maintenance orientation and inspection.

I. Participate in operation and maintenance training sessions.

J. Participate in final review at acceptance meeting.

K. Provide input for final commissioning documentation.

1.6 COMMISSIONING AUTHORITY'S RESPONSIBILITIES

Revise this Article to include Commissioning Authority's responsibilities that have an impact on Contractor activities and responsibilities.

A. Provide Project-specific construction checklists and commissioning process test procedures.

B. Witness systems, assemblies, equipment, and component startup.

C. Compile test data, inspection reports, and certificates and include them in the systems manual and commissioning process report.

1.7 COMMISSIONING DOCUMENTATION

Coordinate activities specified in first paragraph below with Owner-Architect and Architect-Consultant agreements.

A. Provide the following information to Commissioning Authority for inclusion in the Commissioning Plan:

1. Submittals, information for systems manuals, and other required documents and reports.
2. Identification of installed exterior enclosure components, assemblies, systems, and equipment, including design changes that occurred during the construction phase.
3. Certificate of completion, certifying that exterior enclosure assemblies, systems, equipment, and associated controls are complete and ready for testing.
4. Test and inspection reports and certificates.

5. Corrective action documents.

1.8 PRECONSTRUCTION TESTING

A. Preconstruction Mockup Testing: <**Insert commissioning procedures governing mockups and phased mockup testing**>

1.9 COMMISSIONING SUBMITTALS

A. Submit commissioning submittals to Commissioning Authority. Submittals requiring Architect's action will be returned to by [**Architect**] [**Construction Manager, through Architect,**].

1.10 QUALITY ASSURANCE

A. Quality Assurance and Control: Specific commissioning quality-assurance and -control requirements for individual construction activities are specified in the Sections that specify those activities. Specified commissioning tests, inspections, and related actions do not limit Contractor's other quality-assurance and -control procedures that facilitate compliance with the Contract Document requirements.

B. Preconstruction Commissioning Conference: Commissioning Authority will schedule a preconstruction commissioning conference before construction of the exterior enclosurestarts, at a time convenient to Owner[**, Construction Manager,**] Contractor, and Architect, but no later than [**15**] <**Insert number**> days after execution of the Agreement with the Contractor. Allow for the conference to be held at Project site or another convenient location. The Commissioning Authority will conduct the meeting to review commissioning responsibilities and personnel assignments.

Revise first subparagraph below to suit Project.

1. Attendees: Authorized representatives of Owner,[**Construction Manager,**] Commissioning Authority, Architect and consultants; Contractor and its superintendent; major subcontractors; suppliers; and other concerned parties shall attend the conference. All participants at the conference shall be familiar with Project and authorized to conclude matters relating to commissioning.
2. Agenda: Discuss items of significance that could affect progress, including the following:

Add items to list below to suit Project.

a. Commissioning plan
b. Tentative construction schedule.
c. Phasing.
d. Critical work sequencing and long-lead items.
e. Designation of key personnel and their duties.
f. Procedures for testing and inspecting.

g. Submittal procedures.
h. LEED requirements.
i. Preparation of Record Documents.
j. Owner's occupancy requirements.
k. Security.

3. Minutes: [**Commissioning Authority will record**] [**Record**] and distribute meeting minutes.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 VERIFICATION

A. Certify that building exterior enclosure systems, subsystems, and construction have been completed according to the Contract Documents.

B. Commissioning Authority will witness and document field quality-control tests and inspections.

Retain first option in subparagraph below if Owner engages testing and inspection agency. Retain second option if Contractor engages testing and inspection agency.

1. [**Verify**] [**Certify**] that field quality-control testing of building exterior enclosure has been completed and approved, that discrepancies have been corrected, and corrective work approved.

C. Annotate checklist or data sheet when a deficiency is observed.

D. Deferred Testing:

1. If tests cannot be completed because of a deficiency outside the scope of the Building Exterior Enclosure, the deficiency shall be documented and reported to Owner. Deficiencies shall be resolved and corrected by Contractor and tests rescheduled.
2. If the testing plan indicates specific seasonal testing, appropriate initial performance tests shall be completed and documented and additional tests scheduled.

E. Testing Reports:

1. Reports shall include measured data, data sheets, and a comprehensive summary describing the building exterior enclosure systems at the time of testing.
2. Prepare a preliminary test report. Deficiencies will be evaluated by Architect to determine corrective action. Deficiencies shall be corrected and test repeated.

END OF SECTION 019119

Annex L.3: Example Draft Specification -
Section 01811 - Building Exterior Enclosure Commissioning

Enter Project Description:

Enter Project Title:

Enter Date and Status of Document (i.e. BOD, 50% CD, 90% CD, etc.):

SECTION 01811 - BUILDING EXTERIOR ENCLOSURE COMMISSIONING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for non-structural commissioning of the building exterior enclosure, including, but not limited to the following:

1. Below-grade construction, including foundation walls and slabs-on-grade
2. Above-grade construction, including: exterior wall systems and assemblies; steep-slope and low-slope roofing; outdoor plazas, planters and plaza paving systems and assemblies over occupied space, and; glazed window, curtainwall and sloped glazing (skylight) systems
3. Interface conditions (flashings, expansion joints, and sealant) between each of the materials, components and systems that comprise the above and below-grade building exterior enclosure

B. The materials, components, systems, and assemblies that comprise the above and below-grade building exterior enclosure will be evaluated and tested as outlined in this Section, as well as in accordance with each of the technical Sections associated with the design and construction of the building exterior enclosure. The purpose of the Building Exterior Enclosure Commissioning Program (BEECP) will be to provide a process for independent, third-party verification that the installed performance of the building exterior enclosure meets or exceeds the minimum performance requirements set forth by the contract documents for this project.

C. Unless otherwise agreed to in writing between the Owner and Contractor, the BECP will be managed by a registered architect, professional engineer, or other certified commissioning entity (Commissioning Authority) retained by the Owner, and will include, by reference, all requirements set forth by the Architect-of-Record for pre-construction laboratory and field performance testing of the materials, components, systems and assemblies that comprise the building exterior enclosure. In that context, it should be understood by all parties to this project that:

1. Full and complete compliance with the building exterior enclosure performance requirements set forth by the Architect-of-Record in the Basis-of-Design (BOD) for this project will be required to achieve successful “commissioning” of the building exterior enclosure.

2. The requirements of this Section shall in no way relieve the Owner, Contractor, Architect-of-Record and other parties to this project of their respective contractual obligations to the Owner for meeting the specified performance levels in the design and construction of this project.
3. The "commissioning" requirements of the general contractor and sub-contractor or trade responsible for the final detailing and construction of the building exterior enclosure are included under in Part 1 of each of the technical specification Sections included in this Project Manual as they relate to the design and construction of the building exterior enclosure for this project (Divisions 2 through 9).

D. The Commissioning Authority will provide daily and/or weekly written summaries (Reports) of the work in progress during the construction of the building exterior enclosure. These reports will include, but may not be limited to, photographs, sketches and diagrams as required illustrating conditions observed in the field, especially deficiencies noted, together with proposed solutions for those conditions where appropriate for further review and acceptance by the Architect-of-Record for the project. Any changes to the contract documents arising out of the Building Exterior Enclosure Commissioning Program must be submitted, reviewed, and accepted in writing, by the Architect-of-Record and Owner and submitted with a series of details/schematics and material specifications to the Contractor for pricing prior to implementation on the project. The Contractor shall be responsible for coordinating and managing the commissioning responsibilities of each of the subcontractors responsible for the building exterior enclosure.

1.2 RELATED SECTIONS:

1. Division 1 Section 01810 "General Commissioning Requirements" for general requirements for commissioning processes.
2. Division 1 Section 01815 "HVAC Commissioning Requirements" for commissioning the HVAC system and integrated system components interfacing with the building exterior enclosure.

PART 2 - RELATED WORK

2.1 GENERAL CONTRACTOR'S (and/or CONSTRUCTION MANAGEMENT COMPANY) RESPONSIBILITIES

A. Cooperate with the Commissioning Authority personnel and Building Exterior Enclosure Commissioning consultant, provide access to work, and provide adequate schedule for the work for commissioning tasks.

B. Furnish copies of all shop drawings, manufacturer's literature, installation instructions, maintenance information, schedules, warranties or other information as requested.

C. Provide qualified personnel for assistance to complete the commissioning tests, including seasonal testing and all required air and water leakage testing for elements of the building exterior enclosure.

D. Submit a copy of the General Contractor's project and site specific Quality Assurance program to be implemented for construction for review by the Architect of Record, the

Owner and Owner representatives and the Commissioning Authority, including the building exterior enclosure commissioning subconsultant prior to beginning construction and prior to the kick-off meeting of the Building Exterior Enclosure Commissioning Process.

E. Participate and ensure all subcontractors utilized for work on this contract participate in meetings prior to beginning construction with the various members of the design and construction teams, including, but not limited to, the Owner, Owner's representatives, Architect of Record, Commissioning Authority including the building exterior enclosure commissioning subconsultant, Mechanical Engineer, LEED consultant, suppliers, and manufacturer technical representatives. The subcontractors that must attend this meeting include all subcontractors that will be involved in the construction of the building exterior enclosure, including, but not limited to, the roofing, wall system (including installers for the façade system, including, but not limited to, the masonry, stone, metal panel, siding, EIFS, etc. and installers for the air barrier system and drainage plane and flashing and water management system), flashing, sealant, fenestration, concrete, steel, HVAC, electrical, interior framing and drywall contractors. This meeting will be to discuss construction sequencing and the coordination of trades and the General Contractor's project and site-specific Quality Assurance program to be implemented that will be completed during construction of the building exterior enclosure.

F. Have a representative present during laboratory structural and air and water leakage performance testing of building exterior enclosure materials or systems, as required in the individual specification sections in Divisions 2 through 9.

G. The Contractor is to complete and participate in the construction of on-site mock-ups to check constructability, including elements of the building exterior enclosure, as identified in individual sections of the specifications in Divisions 2 through 9, including but not limited to a wall-to-window interfaces and roof-to-wall interfaces and provide personnel to be present and have a representative present from each trade and/or subcontractor associated with installing the system during building exterior enclosure air and water leakage performance testing on the mock-up, as indicated within the individual sections within Divisions 2 through 9. Personnel from each trade that will be completing the work in the field are to be utilized to construct each required mock-up. Provide a written protocol, timeline for repair of any deficiencies noted during the performance testing and/or a written report from the third party agency performing the tests indicating what repairs were required. If a systemic problem is identified during testing, provide repair and remediation protocol for any systemic failures identified by the Commissioning Authority. Include a timeline for repair of all affected elements. Repaired elements shall not be covered up without review by the Commissioning Authority.

H. Chair weekly or bi-weekly Building Exterior Enclosure Quality Assurance Meetings with the appropriate subcontractors in attendance, to review and discuss issues and concerns related to the building exterior enclosure noted by the Architect of Record, the Commissioning Authority, the building exterior enclosure commissioning subconsultant, and the Owner or Owner's representative, during the previous week and what action will be taken to address the noted non-conformances. Maintain a summary of non-conformances and current status.

I. Provide a representative to be present, and have a representative present from each trade and/or subcontractor associated with installing the system during random building exterior enclosure air and water leakage performance testing, as indicated within the individual sections within Divisions 2 through 9. Provide a written protocol and a timeline for repair of any deficiencies noted during the performance testing and/or a written report from the third party agency performing the tests indicating what repairs were required. If a systemic problem is identified during testing, please see the following requirement.

J. Provide a repair and remediation protocol for any systemic failures identified by the Commissioning Authority, including a timeline for repair of all affected elements. Repaired elements shall not be covered up without review and documentation by the Commissioning Authority.

K. Provide copies of all test and inspection reports for inclusion in the Systems Manual to be submitted as part of the project closeout documentation.

L. Provide a Systems Manual as part of the project record closeout documentation that includes, but is not limited to, closeout requirements listed in these specifications and more specifically:

1. As-built drawings, including a copy of all details and drawings that were installed as part of any addendums or change order directives. All deviations shall be clearly marked in red pen.
2. Specifications for the project, including all accepted product substitutions and any additional specifications as part of any addendums or change order directives. All accepted product substitutions and all deviations shall be clearly marked in red pen.
3. A copy of all accepted change orders
4. A copy of all final shop drawings for each product requiring shop drawings, with the A/E mark-ups and comments, showing final as-built conditions
5. A copy of all warranties, organized by product, and any and all product manufacturer letters indicating the product as appropriate to use for the application intended on the project as well as any installation guidance
6. A master product list summarizing all products used on the project for construction of the building exterior enclosure, organized by tabs in a binder, including the following information:

    a. Product name
    b. Product manufacturer
    c. Catalog or other applicable number for ordering
    d. Manufacturer's contact information, including the contact information for the technical representatives, including one national contact and one regional technical representative contact
    e. Product color
    f. Supplier contact information
    g. Products installation instructions, including installation instructions supplied with any of the shop drawings that indicated field installed items.
    h. Manufacturer's product maintenance guide

i. Manufacturer's checklist for periodic review of the product indicating how often the product should be checked and the process for implementing a repair

M. A Systems Manual is to be developed for each major building exterior enclosure system; including, but not limited to:

1. Roof/Garden Roof (penetrations, curbs, etc.)
2. Skylights /Sloped glazing
3. Exterior walls (masonry, stone, EIFS, concrete, precast, metal, insulation, framing, vapor retarder, air barrier, sheathing, etc.)
4. Windows
5. Doors
6. Sealants and expansion joints
7. Control joints
8. Flashings (end dams, drip edges, flexible flashing and metal flashings)
9. Shading devices
10. Curtain walls or window walls, storefronts
11. Plaza decks
12. Planters and planted areas
13. Below-grade construction, waterproofing, drainage
14. Floors, slab-on-grade
15. Fire separation/stopping and smoke control
16. Other special building exterior enclosure systems, equipment and controls.

N. Participate in maintenance orientation and inspection and in one maintenance and training session with the building operations and maintenance staff and other participants identified by the Owner and Architect-of-Record, with the assistance of the Commissioning Authority.

O. Provide labor and facilities:

1. To provide access to work to be tested
2. For Commissioning Authority's exclusive use, for storage of instruments and drawings, records, and preparation of daily reports

2.2 PERFORMANCE REQUIREMENTS

A. Preconstruction Testing of Mockups: See requirements in the individual specification sections in Divisions 2 through 9.

2.3 SUBMITTALS

A. The Contractor is to provide the following submittals to the Commissioning Authority, including the building exterior enclosure-commissioning subconsultant, in addition to submitting them to the Architect-of-Record. These submittals are in addition to those specified in Division 1 Section 01810 "General Commissioning Requirements."

1. Coordination Drawings: Provide cross references on any and all shop drawings indicating that drawings have been checked and cross-referenced by the Contractor to ensure that adjacent elements (i.e. wall elements and fenestration

elements) and the dimensions and construction tolerances indicated will allow all work at interfaces to be constructible

2. Qualifications Data: For fabricators, installers, and testing agencies, submit to the Commissioning Authority for review all qualifications required in Divisions 2 through 9 for review.
3. Preconstruction Test Reports: all preconstruction air and water leakage performance test results, including all failed tests, recording the noted deficiency and the required repair, and provide a copy of all remediation processes and QC/QA processes that will be put in place to address the deficiency on future work product
4. Source Quality Control Reports: retain a copy for field review by the commissioning authority and include in the closeout submittal a copy of all manufacturer QA/QC reports submitted for products supplied for the project
5. Field Quality Control Reports: provide a copy of the test reports for all field water and air penetration and other appropriate building exterior enclosure tests completed
6. Special Inspections Reports for all special inspections indicated by the Architect/Engineer-of-Record in the specifications.

PART 3 - EXECUTION

3.1 COMMISSIONING AUTHORITY'S DUTIES

A. Cooperate with the Architect and Contractor and provide qualified personnel when scheduled.

B. Promptly notify Architect and Contractor of irregularities or deficiencies in work that are observed during performance of services.

C. Be present to observe all testing of all building exterior enclosure systems as defined in the Contract Documents.

D. Commissioning Authority is not authorized to:

1. Release, revoke, alter or expand requirements of Contract Documents.

2. Approve or accept any portion of the work.

3. Perform any duties of the Contractor.

3.2 TESTING VERIFICATION

At substantial completion of the project,

A. The General Contractor is to:

1. Certify that building exterior enclosure systems, subsystems, and construction have been completed according to the Contract Documents, including all addenda and change order requirements.

2. Certify that Field Quality Control procedures have been completed, and that field quality control reports have been submitted, discrepancies corrected, and corrective work approved. Provide a copy of the list of nonconformances maintained by the General Contractor indicating all rework and corrections completed.

B. The Commissioning Authority is to:

1. Verify that Field Quality Control procedures have been completed, and that field quality control reports have been submitted, discrepancies corrected, and corrective work approved.
2. Annotate checklist or data sheets when a deficiency is observed.
3. Verify that field quality-control testing of building exterior enclosure has been completed and approved. The Commissioning Authority shall observe and document field quality-control tests and inspections.

3.3 DEFERRED TESTING:

A. If field tests cannot be completed because of a deficiency outside the scope of the Building Exterior Enclosure, the deficiency shall be documented and reported to the Owner and the Architect-of-Record. Deficiencies shall be resolved and corrected by appropriate parties and the test rescheduled.

3.4 TESTING REPORTS:

A. Testing reports shall include measured data, data sheets, and a comprehensive summary describing the specific building exterior enclosure systems at the time of testing.

B. Prepare a preliminary test report. Deficiencies will be evaluated by the Architect and the Commissioning Authority building exterior enclosure commissioning subconsultant to determine corrective action. Deficiencies shall be corrected and test repeated. All repairs are to be documented by the Commissioning Authority.

C. If it is determined that the system is constructed according to the Contract Documents, the Owner will decide whether modifications are required to bring the performance of the system to a level where the failure or deficiency is eliminated and shall be implemented or if the test results will be accepted as submitted. If corrective Work is performed, the Owner will decide if tests shall be repeated and a revised report is to be submitted.

3.5 SYSTEMS TO BE COMMISSIONED

A. Refer to Divisions 2 through 9 of the Specification Sections for specific requirements for commissioning each building exterior enclosure element and system. The systems and elements to be commissioned include, but are not limited to:

1. Roofs, including the garden roof system, including all penetrations, transitions, etc.
2. Skylights and other sloped glazing
3. Exterior walls, including the air barrier system, and water management systems

4. Windows
5. Doors, louvers
6. Sealants and expansion joints
7. Control joints
8. Flashings, including all transitions, end-dams, etc.
9. Shading devices
10. Curtain walls or window walls, storefront
11. Plaza decks
12. Planters and planted areas
13. Below-grade construction, including drainage and waterproofing/damp proofing
14. Floors, slab-on-grade
15. Interface conditions between each of the above listed elements
16. Fire separation/stopping and smoke control
17. Other special building exterior enclosure systems, equipment and controls.

END OF SECTION 01811

SECTION 01810

COMMISSIONING REQUIREMENTS

PART 1 – GENERAL

1.01 SUMMARY

A. Commissioning: Commissioning is a systematic process of ensuring that all building systems perform interactively according to the Owner's Project Requirements and Performance Criteria. This is achieved by beginning in the design phase and documenting the Owner's Project Requirements and Performance Criteria and continuing through construction, acceptance and the warranty period with actual verification of performance. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment start-up, control system calibration, testing and balancing, as well as performance testing and training.

Commissioning during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:

1. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing contractors.
2. Verify and document proper performance of equipment and systems.
3. Verify that O&M documentation left on site is complete.
4. Verify that the Owner's operating personnel are adequately trained.

B. The commissioning process does not take away from or reduce the responsibility of the system designers or installing contractors to provide a finished and fully functioning product.

C. Abbreviations: The following are common abbreviations used in the *Specifications* and in the *Commissioning Plan.* Definitions are found in 1.06 of this Section.

A/E =	Architect And Design Engineers	MC =	Mechanical Contractor
CxA =	Commissioning Authority	O&M =	Operations & Maintenance
CC =	Controls Contractor	CK =	Construction Checklist
EC =	Electrical Contractor	PM =	Project Manager (Of AMB Realty)
Test =	Performance Test	SC =	Sealant Contractor
GC	General Contractor	SMC =	Sheet Metal Contractor
GLC =	Glazing Contractor	Subs =	Subcontractors To GC
HVAC =	Heating, Ventilation & Air Conditioning	TABC =	Test And Balance Contractor
LVC =	Limestone Veneer Contractor		

D. Related Sections: Specific commissioning requirements are given in the following sections of these Specifications. All of the following sections apply to the work of this section.
1. Section 00800 – Supplementary Conditions
2. Section 01311 – Project Coordination
3. Section 01312 – Project Meetings
4. Section 01330 – Submittal Procedures
5. Section 01450 – Quality Control
6. Section 01780 – Closeout Submittals
7. Section 01810 – Commissioning Requirements
8. Section 01811 – Fenestration System Testing Requirements
9. Section 01812 – Mechanical System Testing Requirements
10. Section 01813 – Electrical System Testing Requirements
11. Section 01820 – Demonstration and Training
12. Section 01830 – Operation and Maintenance
13. Section 04080 – Masonry Anchorage and Reinforcement
14. Section 04210 – Brick
15. Section 04220 – Concrete Masonry Units
16. Section 04450 – Limestone Veneer
17. Section 07260 – Vapor Barriers
18. Section 07412 – Metal Wall Panels
19. Section 07600 – Flashing and Sheet Metal
20. Section 07650 – Flexible Flashing
21. Section 07920 – Joint Sealants
22. Section 08550 – Wood Windows
23. Section 08800 – Glazing
24. Section 15010 – Mechanical General
25. Section 16010 – Electrical General

E. The purpose of this section is to specify responsibilities in the commissioning process.

F. Systems to be commissioned are listed in Section 01810, Part 1.06

G. Commissioning requires the participation of the project team as defined in Section 1810, Part 1.03 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Section 01810. The project team shall be familiar with all parts of Section 01810 and the Commissioning Plan issued by the CxA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.02 DEFINITIONS

Acceptance Phase: phase of construction after start-up and initial checkout when performance tests, O&M documentation review and training occurs.

Approval: acceptance that a piece of equipment or system has been properly installed and is functioning in the tested modes according to the contract documents.

Architect / Engineer (A/E): the prime consultant (architect) and sub-consultants who comprise the design team, generally the HVAC mechanical designer/engineer and the electrical designer/engineer.

Commissioning Authority (CxA): an independent agent, not otherwise associated with the A/E team members or the contractor who directs and coordinates the day-to-day commissioning activities. The CxA does not take an oversight role like the PM. The CxA shall report directly to the PM.

Commissioning Plan: an overall plan, developed before or after bidding, that provides the structure, schedule, and coordination planning for the commissioning process.

Contract Documents: the documents binding on parties involved in the construction of this project (Drawings, Specifications, Change Orders, Amendments, Contracts, *Commissioning Plan*, etc.).

Contractor: the general contractor or authorized representative.

Control system: the central building energy management control system.

Data-logging: monitoring flows, currents, status, pressures, etc. of equipment using stand-alone data-loggers separate from the control system.

Deferred Tests: FTs that are performed later, after substantial completion, due to partial occupancy, equipment, seasonal requirements, design or other site conditions that prevent the test from being performed.

Deficiency: a condition in the installation or function of a component, piece of equipment or system that is not in compliance with the *Contract Documents* (that is, does not perform properly or is not complying with the design intent).

Design Basis: the basis, rationale, and assumptions for calculations, decisions, schemes, and system and assemblies selected to meet the *Owner's Project Requirements* and to satisfy applicable regulatory requirements, standards, and guidelines.

Design Narrative: the written description of the concepts and features the designer intends (during schematics) to incorporate into the design or what they have incorporated to meet the *Owner's Project Requirements* and associated *Performance Criteria*.

Factory Testing: testing of equipment on-site or at the factory by factory personnel with an Owner's representative present.

Performance Test (Test): test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Testing is the dynamic testing of systems (rather than just components) under full operation (e.g., the chiller pump is tested interactively with the chiller functions to see if the pump ramps up and down to maintain the differential pressure setpoint). Systems are tested under various modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, etc. The systems are run through all the control system's sequences of operation and components are verified to be responding as the sequences state. Traditional air or water test and balancing (TAB) is not testing, in the commissioning sense of the word. TAB's primary work is setting up the system flows and pressures as specified, while testing is verifying that which has already been set up. The CxA develops the test procedures in a sequential written form, coordinates, oversees and documents the actual testing, which is usually performed by the Installing Contractor or vendor. Tests are performed after construction checklists and start-up is complete.

General Contractor (GC): the prime contractor for this project. Generally refers to all the GC's subcontractors as well. Also referred to as the contractor, in some contexts.

Indirect Indicators: indicators of a response or condition, such as a reading from a control system screen reporting a damper to be 100% closed.

Manual Test: using hand-held instruments, immediate control system readouts or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the "observation").

Monitoring: the recording of parameters (flow, current, status, pressure, etc.) of equipment operation using data-loggers or the trending capabilities of control systems.

Non-Compliance: see "Deficiency."

Non-Conformance: see "Deficiency."

Over-written Value: writing over a sensor value in the control system to see the response of a system (e.g., changing the outside air temperature value from 50F to 75F to verify economizer operation). See also "Simulated Signal."

Owner-Contracted Tests: tests paid for by the Owner outside the GMP's contract, which the CxA does not oversee. These tests will not be repeated during tests if properly documented.

Owner's Project Requirements (OPR): written documentation of the functional requirements of a facility and the expectations of how the facility will be used and operated. This documentation includes project and design goals, budgets, limitations, schedules, owner directives, and supporting information. OPRs are addressed to all disciplines necessary to properly plan, design, construct, operate, and maintain systems and assemblies.

Performance Criteria: indicators that allow verification that a specific Owner Requirement or element in the Design Narrative or Design Basis has been met.

Phased Commissioning: Commissioning that is completed in phases (by floors, for example) due to the size of the structure or other scheduling issues, in order minimize the total construction time.

Construction Checklist (CK): a list of items to inspect and elementary component tests to conduct to verify proper installation of equipment or systems, provided by the CxA to the Sub. Construction checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels OK, labels affixed, gages in place, sensors calibrated, etc.). However, some construction checklist items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a three phase pump motor of a chiller system). The word construction refers to before acceptance testing. Construction checklists augment and are combined with the manufacturer's start-up checklist. Even without a commissioning process, contractors typically perform some, if not many, of the Construction checklist items a CxA will recommend. However, few contractors document in writing the execution of these checklist items. Therefore, for most equipment, the contractors execute the checklists on their own. The CxA only requires that the procedures be documented in writing, and does not witness the majority of construction checklist, except for larger or more critical pieces of equipment.

Project Manager (PM): the contracting and managing authority for AMB Realty over the design and/or construction of the project.

Sampling: functionally testing only a fraction of the total number of identical or near identical pieces of equipment. Refer to Section 01810, Part 3.6, F for details.

Seasonal Performance Tests: FT that is deferred until the system(s) will experience conditions closer to their design conditions.

Simulated Condition: condition that is created for the purpose of testing the response of a system (e.g., applying a hair blower to a space sensor to see the response in a VAV box).

Simulated Signal: disconnecting a sensor and using a signal generator to send an amperage, resistance, or pressure to the transducer and DDC system to simulate a sensor value.

Specifications: the construction Specifications of the Contract Documents.

Start-up: the initial starting or activating of dynamic equipment, including executing construction checklists.

Subs: the subcontractors to the GC who provide and install building components and systems.

Test Procedures: the step-by-step process which must be executed to fulfill the test requirements. The test procedures are developed by the CxA.

Test Requirements: requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures. The test requirements are specified in the Contract Documents (Sections 01811, 01812, 01813).

Trending: monitoring using the building control system.

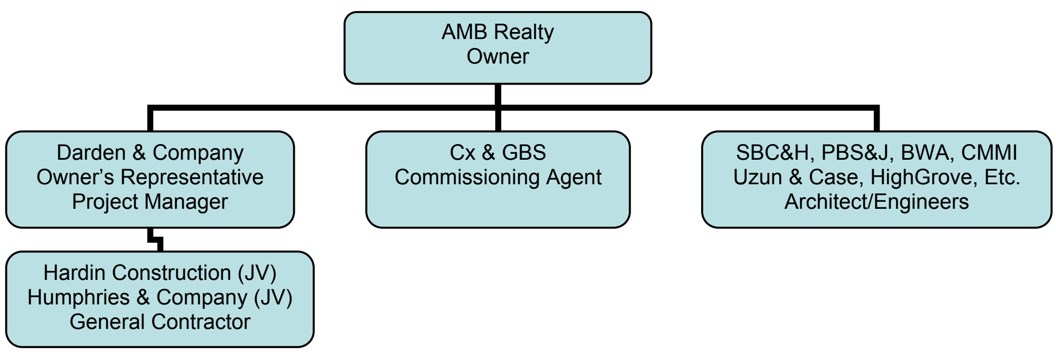
Vendor: supplier of equipment.

Warranty Period: warranty period for entire project, including equipment components. Warranty begins at Substantial Completion and extends for at least one year, unless specifically noted otherwise in the Contract Documents and accepted submittals.

1.03 COORDINATION

A. Commissioning Team: The members of the commissioning team consist of the contract CxA, the construction representative of the Owner – The Owner's PM, the GC, the A/E, the MC, the EC, the TABC, the CC, the SC, the SMC, LVC, the GLC, and any other installing subcontractors or suppliers of equipment. Also, if known, the Plant Operations building mechanic is also a member of the commissioning team.

B. Management: The contract CxA is hired by the Owner directly. The CxA directs and coordinates the project commissioning activities and the reports to Darden & Company the PM. All team members work together to fulfill their contracted responsibilities and meet the objectives of the contract documents. The following organization chart clarifies the roles.



C. Scheduling: The CxA will work with the PM and GC according to established protocols to schedule the commissioning activities. The CxA will provide sufficient notice to the PM and GC for scheduling commissioning activities. The GC will integrate all commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process.

The CxA will provide the initial schedule of primary commissioning events at the commissioning kickoff and scoping meetings. The *Commissioning Plan – Construction Phase* provides a format for this schedule. As construction progresses, more detailed schedules are developed by the CxA. The Commissioning Plan also provides a format for detailed schedules.

1.04 COMMISSIONING PROCESS

A. Commissioning Plan: The *Commissioning Plan* provided as part of the bid documents, is binding on the contractor. The Commissioning Plan provides guidance in the execution of the commissioning process. Just after the initial commissioning scoping meeting, the CxA will update the plan that is then considered the "final" plan, though it will continue to evolve and expand as the project progresses. The *Specifications* will take precedence over the *Commissioning Plan*.

B. Commissioning Process: The following narrative provides a brief overview of the typical commissioning tasks during construction and the general order in which they occur.

1. Commissioning during construction begins with a scoping meeting conducted by the CxA where the commissioning process is reviewed with the commissioning team members.
2. Additional meetings will be required throughout construction, scheduled by the CxA with necessary parties attending to plan, scope, coordinate, schedule future activities and resolve problems.
3. Equipment documentation is submitted to the CxA during normal submittals, including detailed start-up procedures.
4. The Contractor develops start-up plans for review and approval by the CxA.
5. The Contractor and appropriate Subs provide their standard checklists to the CxA who will use them to develop CK's the contractors' will complete prior to testing.
6. In general, the checkout and performance verification proceeds from simple to complex, from component level to equipment to systems and intersystem levels with CKs being completed before testing.
7. The Contractor and Subs, under their own direction, execute and document the CKs and perform start-up and initial checkout. The CxA documents that the checklists and start-up were completed according to the approved plans. This may include the CxA witnessing start-up of selected equipment.
8. The CxA performs periodic construction observations.
9. The CxA develops specific equipment and system FT procedures. The contractors' and A/E review the procedures and provide appropriate comments.
10. The procedures are executed by the Contractor and Subs, under the direction of, and documented by the CxA.
11. Items of non-compliance in material, installation or setup are corrected at the contractors' expense and the system or building's envelop assembly re-tested. Additional retesting shall be in accordance with Section 01450 – Quality Control.

12. The CxA reviews the O&M documentation for completeness.
13. Commissioning is completed before substantial completion, except for thermographs of electrical systems as required in Section 01813; trend log monitoring, seasonal testing, near-warranty end activities, verification of training sessions.
14. The CxA reviews, pre-approves and coordinates the training provided by the Contractor and Subs and verifies that it was completed.
15. Deferred testing is conducted, as specified or required.

1.05 RESPONSIBILITIES

A. The responsibilities of the non-Contractor parties in the commissioning process are summarized in the following articles. It is noted that the services for the PM, Architect, mechanical and electrical designers/engineers, and Commissioning Authority are not provided for in this contract. That is, the Contractor is not responsible for providing their services. Their responsibilities are listed here to clarify the commissioning process. Additional responsibilities of subcontractors to the Contractor are found in other sub-sections of 01800.

B. The responsibilities of various parties in the commissioning process are provided in this section. These responsibilities of the A/E, CxA shown here are not intended to alter their contractual responsibilities to the Owner. These responsibilities have been established by separate contracts of the said parties with the Owner. Their responsibilities are listed here to clarify the commissioning process. The responsibilities of the LVC, SMC, SC, GLC, MC, TABC, CC are in 01810 and other Sections referred to in 01810.

C. All Parties

1. Follow the Commissioning Plan.
2. Attend commissioning scoping meeting and additional meetings, as necessary.

D. Architect (of A/E)

Construction and Acceptance Phase

1. Does not manage the CxA's contract; said contract managed directly by AMB Realty.
2. Attend the commissioning kickoff and scoping meetings and selected commissioning team meetings.
3. Perform normal submittal review, construction observation, as-built drawing preparation, O&M manual preparation, etc., as contracted.
4. Provide design narrative documentation requested by the CxA.

5. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
6. Prepare and submit record drawings and documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.

Warranty Period

1. Coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning.

E. Mechanical and Electrical Designers/Engineers (of the A/E)

Construction and Acceptance Phase

1. Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted with Owner. One site observation should be completed just prior to system start-up.
2. Provide design narrative and sequences documentation requested by the CxA. The designers shall assist (along with the contractors) in clarifying the operation and control of commissioned equipment in areas where the Specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
3. Attend commissioning kickoff and scoping meetings and other selected commissioning team meetings as contracted with the Owner.
4. Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
5. Prepare and submit record drawings and documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.
6. Provide a presentation at the first training session for the Owner's personnel.
7. Approve the CKs for major pieces of equipment for sufficiency prior to their use.
8. Approve the FT procedure forms for major pieces of equipment for sufficiency prior to their use.

Warranty Period

1. Participate in the resolution of non-compliance, non-conformance and design deficiencies identified during commissioning during warranty-period commissioning.

F. CxA: The CxA is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management. The CxA may assist with problem-solving, non-conformance or deficiencies, but ultimately that responsibility resides with the GC and the A/E. The primary role of the CxA is to develop and coordinate the execution of a testing plan, observe and document performance—that systems are functioning in accordance with the documented Owner's Project Requirements and Performance Criteria and in accordance with the Contract Documents. The contractors will provide all tools or the use of tools to start, access equipment, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CxA.

Construction and Acceptance Phase

1. Coordinates and directs the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.
2. Coordinate the commissioning work and, with the GC and PM, ensure that commissioning activities are being scheduled into the master schedule.
3. Revise, as necessary, Commissioning Plan—Construction Phase.
4. Plan and conduct a commissioning kickoff and scoping meetings.
5. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures. Before start-up review current control sequences and interlocks and work with contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
6. Develop the format for, and coordinate the completion of the emergency power and fire alarm response matrix as defined in this section.
7. Review normal contractor submittals applicable to systems being commissioned concurrent with the A/E reviews for compliance with commissioning, O & M needs, and coordination issues.
8. Write and distribute prerequisite checklists for commissioned equipment.
9. Develop an enhanced start-up and initial systems checkout plan with contractors for selected equipment.
10. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving discrepancies.
11. Coordinate with the project sustainable design or LEED coordinator to verify that any sustainable design requirements affected by system performance or commissioning are addressed.
12. Document construction checklist completion by reviewing completed construction checklists and by selected site observation

13. Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify Owners project manager of any deficiencies in results or procedures.
14. Witness all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify Owner's project manager of any deficiencies in results or procedures.
15. Document systems start-up by reviewing start-up reports and by selected site observation.
16. Write performance test procedures for equipment and systems. This will include manual testing, energy management control system trending and may include stand-alone data-logger monitoring. The CxA will write detailed test procedures for all commissioned equipment, systems and assemblies, and submit to PM, contractors' and A/E for review and approval unless noted otherwise in the specifications
17. Review TAB execution plan.
18. Witness sufficient testing of the control system to verify it may be used for TAB, before TAB is executed.
19. Verify air and water systems balancing by spot testing, by reviewing completed reports and by selected site observation.
20. Analyze performance trend logs and monitoring data to verify performance.
21. Coordinate through GC and PM, witness and verify manual FTs performed by Installing Contractors. Coordinate re-testing as necessary until satisfactory performances achieved.
22. Maintain a master deficiency and resolution log and a separate testing record. Provide the PM and A/E with written progress reports and test results with recommended actions.
23. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
24. Oversee and verify the training of the Owner's operating personnel.
25. Compile and maintain a Commissioning Record and Building Systems book(s).
26. Review and verify the preparation of the O&M manuals.
27. Provide a Final Commissioning Report.

Warranty Period

1. Coordinate and supervise required seasonal or deferred testing and deficiency corrections.
2. Return to the site at 10 months into the 12-month warranty period and review with facility staff the current building operation and the condition of

outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.

3. Optional: Assist in the development of a preventative maintenance plan, a detailed operating plan or an energy and resource management plan or as-built documentation.

G. Owner's Project Manager (PM)

Construction and Acceptance Phase

1. Facilitate the coordination of the commissioning work by the CxA, and with the GC and CxA, ensure that commissioning activities are being scheduled into the master schedule.
2. Review and approve the final Commissioning Plan—Construction Phase.
3. Attend a commissioning kickoff and scoping meetings and other commissioning team meetings.
4. Perform the normal review of contractor submittals.
5. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CxA.
6. Review and approve the FT procedures submitted by the CxA, prior to testing.
7. When necessary, observe and witness CK, start-up and testing of selected equipment.
8. Review commissioning progress and deficiency reports.
9. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.
10. Sign-off (final approval) on individual commissioning tests as completed and passing.
11. Assist the GC in coordinating the training of Owner personnel.
12. Manage the contract of the A/E and of the GC.

Warranty Period

1. Assist the CxA as necessary in the seasonal or deferred testing and deficiency corrections required by the Specifications.

H. General Contractor

Construction and Acceptance Phase

1. Facilitate the coordination of the commissioning work by the CxA, and with the Subs and CxA to ensure that commissioning activities are being scheduled into the master schedule.
2. Include the cost of commissioning in the contract price. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CxA.
3. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CxA.
4. In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and training.
5. Ensure that all Subs execute their commissioning responsibilities according to the contract documents and schedule.
6. A representative shall attend a commissioning scoping meeting and other necessary meetings scheduled by the CxA to facilitate the commissioning process.
7. Coordinate the training of Owner personnel.
8. Prepare O&M manuals, according to the contract documents, including clarifying and updating the original sequences of operation to as-built conditions.

Warranty Period

1. Ensure that Subs execute seasonal or deferred performance testing, witnessed by the CxA, according to the Specifications.
2. Ensure that Subs correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

I. Building Envelop Contractors

Construction and Acceptance Phases

1. Attend a commissioning scoping meeting and other meetings necessary to facilitate the commissioning process.
2. Contractors shall provide the CxA with normal cut sheets and shop drawing submittals of commissioned components and composite assemblies.
3. Provide additional requested documentation, prior to completion of mock-up assemblies, to the CxA for finalizing testing procedures.
   a. Typically this will include detailed manufacturer installation instructions, testing laboratory certifications/reports, maintenance procedures, full details of any Owner-contracted tests, full factory testing reports, and full warranty information, including all responsibilities of the Owner to keep

the warranty in force clearly identified. In addition, the installation materials that are actually shipped with the exterior wall components and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the CxA.

b. The CxA may request further documentation necessary for the commissioning process.

c. This data request may be made prior to normal submittals.

4. Provide a copy of the submittals of commissioned building envelope components, through normal channels, to the CxA for review and comment. O&M data shall be provided in accordance with Section 01780.

5. Contractors shall assist (along with the design professionals) in clarifying the installation and operation of commissioned assemblies in areas where the Specifications or component/assembly documentation is not sufficient for writing detailed testing procedures.

6. Provide limited assistance to the CxA in preparing the specific performance test procedures required. Subs shall review test procedures to ensure feasibility, safety and material protection during tests.

7. Develop initial and full checkout plan using manufacturer's procedures and the CKs for all commissioned assemblies. Submit to CxA for review and approval prior to proceeding with installation of building envelope.

8. During the initial checkout process execute the CKs for all components of the exterior wall assembly to be commissioned.

9. Perform and clearly document all completed checkout procedures, providing a signed and dated certification copy to the CxA.

10. Conduct testing before installation of insulation and interior closure of the wall. Address current A/E punch list items before testing. The exterior sections of the building envelope assemblies shall be completed with discrepancies and problems remedied before testing of the exterior wall system or mock-up assemblies.

11. Exterior Wall Contractors will provide installation foreman to witness execution of the FTs conducted on the mock-up assemblies to resolve installation issues and establish future installation practices necessary to correct deficiencies observed prior to commencing with installation of the exterior wall systems. Exterior Wall Contractors will ensure that the installation foremen are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving.

12. Provide access to scaffolding, man-lifts, or other mechanical conveyances used by the exterior wall contractors to perform their work during performance testing under the direction of the CxA. If subcontractor's schedule does not allow use of mechanical conveyances for commission activities, the GC will provide the necessary equipment for access required for commissioning.

13. Correct deficiencies as interpreted by the CxA, GC, PM and A/E and retest as required.
14. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the as-built conditions.
15. Prepare redline as-built drawings for all drawings and final as-built drawings.
16. Provide training of the Owner's operating personnel as specified.
17. Coordinate with system manufacturers to determine specific requirements to maintain the validity of the warranty.
18. Prepare a preliminary schedule for exterior wall assemblies testing for use by the CxA. Update the schedule as appropriate.
19. Notify the GC and CxA when exterior wall assemblies testing are ready to occur. Be responsible to notify the GC and CxA, ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Take an active roll in seeing that commissioning processes are executed and that the CxA has the scheduling information needed to efficiently execute the commissioning process.

J. Mechanical, Controls, and HVAC Test & Balance contractors

Construction and Acceptance Phases

1. In each purchase order or subcontract written, include requirements for submittal data, commissioning documentation, O&M data and training.
2. Attend a commissioning scoping meeting and other meetings necessary to facilitate the commissioning process.
3. Contractors shall provide the CxA with normal cut sheets and shop drawing submittals of commissioned equipment.
4. Provide additional requested documentation, prior to normal O&M manual submittals, to the CxA for development of start-up and testing procedures.
    a. Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any Owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation, start-up and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the CxA.
    b. The CxA may request further documentation necessary for the commissioning process.
    c. This data request may be made prior to normal submittals.

5. Provide a copy of the O&M manuals and submittals of commissioned equipment, through normal channels, to the CxA for review and comment concurrent with normal submittal reviews.
6. Contractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the Specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
7. Provide limited assistance to the CxA in preparing the FT procedures as specified in Section 01812. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
8. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the CK from the CxA for all commissioned equipment. Submit to CxA for review and approval prior to start-up. Refer to Section 01810 for further details on start-up plan preparation.
9. During the start-up and initial checkout process, execute the mechanical-related portions of the CKs for all commissioned equipment.
10. Perform and clearly document all completed start-up and system operational checkout procedures, providing a copy to the CxA.
11. Address current A/E punch list items before testing. Air and water TAB shall be completed with discrepancies and problems remedied before testing of the respective air- or water-related systems.
12. Provide skilled technicians to execute starting of equipment and to execute the FTs. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
13. Provide skilled technicians to perform performance testing under the direction of the CxA for specified equipment in Sections 01810 and 01811. Assist the CxA in interpreting the monitoring data, as necessary.
14. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxA, GC and A/E and retest the equipment.
15. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
16. During construction, maintain as-built red-line drawings for all drawings and final CAD as-builts for contractor-generated coordination drawings. Update after completion of commissioning (excluding deferred testing).
17. Provide training of the Owner's operating staff using expert qualified personnel, as specified.
18. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

Warranty Period

1. Execute seasonal or deferred performance testing, witnessed by the CxA, according to the Specifications.
2. Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

K. MC: The responsibilities of the HVAC MC, during construction and acceptance phases in addition to those listed in (J) are:

1. Provide start-up for all HVAC equipment, except for the building automation control system.
2. Assist and cooperate with the TABC and CxA by:
    a. Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
    b. Including cost of sheaves and belts that may be required by TAB.
    c. Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Provide an approved plug.
    d. Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.
3. Install a P/T plug at each water sensor which is an input point to the control system.
4. List and clearly identify on the as-built drawings the locations of all air-flow stations.
5. Prepare a preliminary schedule for Division 15 pipe and duct system testing, flushing and cleaning, equipment start-up and TAB start and completion for use by the CxA. Update the schedule as appropriate.
6. Notify the GC when pipe and duct system testing, flushing, cleaning, start-up of each piece of equipment and TAB will occur. Be responsible to notify the GC ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed and that the CxA has the scheduling information needed to efficiently execute the commissioning process.

L. CC: The commissioning responsibilities of the CC, during construction and acceptance phases in addition to those listed in (J) are:

1. Sequences of Operation Submittals: The CC's submittals of control drawings shall include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the Specifications. They shall include:

a. An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components and function.
b. All interactions and interlocks with other systems.
c. Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable.
d. Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included, but will generally require additional narrative).
e. Start-up sequences.
f. Warm-up mode sequences.
g. Normal operating mode sequences.
h. Unoccupied mode sequences.
i. Shutdown sequences.
j. Capacity control sequences and equipment staging.
k. Temperature and pressure control: setbacks, setups, resets, etc.
l. Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
m. Effects of power or equipment failure with all standby component functions.
n. Sequences for all alarms and emergency shut downs.
o. Seasonal operational differences and recommendations.
p. Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
q. Schedules, if known.
r. To facilitate referencing in testing procedures, all sequences shall be written in small statements, each with a number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

2. Control Drawings Submittal

a. The control drawings shall have a key to all abbreviations.
b. The control drawings shall contain graphic schematic depictions of the systems and each component.
c. The schematics will include the system and component layout of any equipment that the control system monitors, enables or controls, even if the equipment is primarily controlled by packaged or integral controls.
d. Provide a full points list with at least the following included for each point:

1) Controlled system
2) Point abbreviation
3) Point description
4) Display unit
5) Control point or setpoint
6) Monitoring point
7) Intermediate point
8) Calculated point

Key:

Point Description: DB temp, airflow, etc.

Control or Setpoint: Point that controls equipment and can have its setpoint changed (OSA, SAT, etc.)

Intermediate Point: Point whose value is used to make a calculation which then controls equipment (space temperatures that are averaged to a virtual point to control reset).

Monitoring Point: Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification.

Calculated Point: "Virtual" point generated from calculations of other point values.

The CC shall keep the CxA informed of all changes to this list during programming and setup.

3. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.
4. Assist and cooperate with the TABC in the following manner:
   a. Meet with the TABC prior to beginning TAB and review the TAB plan to determine the capabilities of the control system toward completing TAB. Provide the TABC any needed unique instruments for setting terminal unit boxes and instruct TABC in their use (handheld control system interface for use around the building during TAB, etc.).
   b. For a given area, have all required CKs, calibrations, start-up and selected FTs of the system completed and approved by the CxA prior to TAB.
   c. Provide a qualified technician to operate the controls to assist the TABC n performing TAB, or provide sufficient training for TABC to operate the system without assistance.
5. Assist and cooperate with the CxA in the following manner:

a. Using a skilled technician who is familiar with this building, execute the testing of the controls system as specified for CC in Sections 01812 and 01813. Assist in the testing of all equipment specified in Sections 01812 and 01813. Provide two-way radios during the testing.

b. Execute all control system trend logs specified in Sections 01811 and 01812.

6. The CC shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to performance testing, according to the process in Section 01810. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:

   a. System name.
   b. List of devices.
   c. Step-by-step procedures for testing each controller after installation, including:

      1) Process of verifying proper hardware and wiring installation.
      2) Process of downloading programs to local controllers and verifying that they are addressed correctly.
      3) Process of performing operational checks of each controlled component.
      4) Plan and process for calibrating valve and damper actuators and all sensors.
      5) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.

   d. A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor or controller has “passed” and is operating within the contract parameters.
   e. A description of the instrumentation required for testing.
   f. Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CxA and TABC for this determination.

7. Provide a signed and dated certification to the CxA and GC upon completion of the checkout of each controlled device, equipment and system prior to testing for each piece of equipment or system, that all system programming is complete as to all respects of the Contract Documents, except testing requirements.

8. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as specified in Section 15900.
9. List and clearly identify on the as-built duct and piping drawings the locations of all static and differential pressure sensors (air, water and building pressure).

M. TABC: The duties of the TABC, in addition to those listed in (J) are:

1. Submit the outline of the TAB plan and approach for each system and component to the CxA, GC and the CC six (6) weeks prior to starting the TAB. This plan will be developed after the TABC has some familiarity with the control system.
2. The submitted plan will include:
   a. Certification that the TABC has reviewed the construction documents and the systems with the design engineers and contractors to sufficiently understand the design intent for each system.
   b. An explanation of the intended use of the building control system. The CC will comment on feasibility of the plan.
   c. All field checkout sheets and logs to be used that list each piece of equipment to be tested, adjusted and balanced with the data cells to be gathered for each.
   d. Discussion of what notations and markings will be made on the duct and piping drawings during the process.
   e. Final test report forms to be used.
   f. Detailed step-by-step procedures for TAB work for each system and issue: terminal flow calibration (for each terminal type), diffuser proportioning, branch / sub-main proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions, etc. Criteria for using air flow straighteners or relocating flow stations and sensors will be discussed. Provide the analogous explanations for the water side.
   g. List of all air flow, water flow, sound level, system capacity and efficiency measurements to be performed and a description of specific test procedures, parameters, formulas to be used.
   h. Details of how *total* flow will be determined (Air: sum of terminal flows via BAS calibrated readings or via hood readings of all terminals, supply (SA) and return air (RA) pitot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic, etc.).
   i. The identification and types of measurement instruments to be used and their most recent calibration date.
   j. Specific procedures that will ensure that both air and water side are operating at the lowest possible pressures and provide methods to verify this.

k. Confirmation that TAB understands the outside air ventilation criteria under all conditions.

l. Details of whether and how minimum outside air cfm will be verified and set, and for what level (total building, zone, etc.).

m. Details of how building static and exhaust fan / relief damper capacity will be checked.

n. Proposed selection points for sound measurements and sound measurement methods.

o. Details of methods for making any specified coil or other system plant capacity measurements.

p. Details of any TAB work to be done in phases (by floor, etc.), or of areas to be built out later.

q. Details regarding specified deferred or seasonal TAB work.

r. Details of any specified false loading of systems to complete TAB work.

s. Details of all exhaust fan balancing and capacity verifications, including any required room pressure differentials.

t. Details of any required interstitial cavity differential pressure measurements and calculations.

u. Plan for hand-written field technician logs of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests (scope and frequency).

v. Plan for formal progress reports (scope and frequency).

w. Plan for formal deficiency reports (scope, frequency and distribution).

3. A running log of events and issues shall be kept by the TAB field technicians. Submit hand-written reports of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests to the CxA and GC as agreed to in the commissioning meeting.

4. Communicate in writing to the CC all setpoint and parameter changes made or problems and discrepancies identified during TAB which affect the control system setup and operation.

5. Provide a draft TAB report within two weeks of completion. A copy will be provided to the CxA. The report will contain a full explanation of the methodology, assumptions and the results in a clear format with designations of all uncommon abbreviations and column headings. The report should follow the latest and most rigorous reporting recommendations by AABC, NEBB or ASHRAE Standard 111.

6. Provide the CxA with any requested data, gathered, but not shown on the draft reports.

7. Provide a final TAB report for the CxA with details, as in the draft.

8. Conduct FTs and checks on the original TAB as specified for TAB in Section 01812.

N. Electrical Contractor: The commissioning responsibilities applicable to the EC are as follows *(all references apply to commissioned equipment only)*:

Construction and Acceptance Phases

1. The contractor shall provide submittal data, O&M data and training as outlined by the CxA.
2. Attend a commissioning scoping meeting and other necessary meetings scheduled by the CxA to facilitate the commissioning process.
3. Contractors shall provide normal cut sheets and shop drawing submittals to the CxA of commissioned equipment.
4. Provide additional requested documentation, prior to normal O&M manual submittals, to the CxA for development of start-up and testing procedures.
   a. Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any Owner-contracted tests, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the CxA.
   b. The CxA may request further documentation necessary for the commissioning process.
5. Provide a copy of the O&M manual submittals of commissioned equipment, through normal channels, to the CxA for review.
6. Contractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the Specifications, control drawings or equipment documentation are not sufficient for writing detailed testing procedures.
7. The contractor shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
8. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the CKs from the CxA. Submit manufacturer's detailed start-up procedures and the full start-up plan and procedures and other requested equipment documentation to CxA for review.
9. During the start-up and initial checkout process, execute and document the electrical-related portions of the CKs provided by the CxA for all commissioned equipment.
10. Perform and clearly document all completed start-up and system operational checkout procedures, providing a copy to the CxA for review.
11. Address current A/E punch list items before testing.

12. Provide skilled technicians to execute starting of equipment and to execute the FTs. Ensure that they are available and present during the agreed-upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving.
13. Perform testing as outlined by the CxA for the specified equipment. Assist the CxA in interpreting the test data, as necessary.
14. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxA, PM and A/E and retest the equipment.
15. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
16. Prepare red-line, as-built drawings that properly identify all field conditions from contractor-generated coordination drawings.
17. Provide training of the Owner's operating personnel as specified and as outlined in the Commissioning Plan.
18. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

Warranty Period

1. Execute deferred performance testing as required.
2. Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

O. Equipment/Material Suppliers

1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner to keep warranties in force.
2. Assist in equipment testing per agreements with Subs.
3. Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these contract documents in the base bid price to the contractor, except for stand-alone data-logging equipment that may be used by the CxA.
4. Provide information requested by CxA regarding equipment sequence of operation and testing procedures.
5. Review test procedures for equipment installed by factory representatives.

1.06 SYSTEMS TO BE COMMISSIONED

A. The following systems will be commissioned in this project:

1. Building Envelope
   a. Limestone Veneer

   b. Sheet metal flashing and trim
   c. Joint sealants
   d. Windows
   e. Glazing
2. Mechanical and Related Systems
   a. Air Handling Systems
   b. Chilled Water System
   c. Heating System
   d. Cooling Towers
   e. Energy Management and Control System
   f. Testing and Balancing Verification Requirements
   g. Independent Exhaust, Relief, and Ventilation Fans
   h. Fire Protection and Fire Alarm Test Coordination Requirements
   i. Domestic Hot Water System
   j. Plumbing System Test Coordination Requirements
   k. Water Feature
   l. Variable Speed Drives
3. Electrical and Related Systems
   a. Service Switch Gear
   b. Switchboards
   c. Distribution Panelboards
   d. Transformers
   e. Motor Control Centers
   f. Power Monitoring and Metering
   g. Transient Voltage Surge Supressors
   h. Variable Speed Drives
   i. Grounding and Ground Fault Systems
   j. Overcurrent Protective Devices
   k. Thermographic Survey
   l. Lighting Control
   m. Emergency Generators and Transfer Switches

1.07 SUBMITTALS

A. The Contractor shall provide the Commissioning Authority with information required to facilitate the commissioning process from a written request. These requests may be integrated into the normal submittal process. At minimum, the request will include the normal submittals and shop drawings, the manufacturer's printed installation and detailed start-up procedures, full sequences of operation, O&M data, and performance data, any performance test procedures, control drawings and details of owner contracted tests. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Authority. This documentation will be required prior to the normal O&M manual submittals. All documentation requested by the Commissioning Authority shall be obtained and included by the contractor later in the O&M manuals.

B. The Commissioning authority will review and approve submittals related to the commissioned equipment for conformance to the Contract Documents as it relates to the commissioning process, to the performance of the equipment, adequacy for developing test procedures and for O&M issues. This review is intended primarily to aid in the development of testing procedures and only secondarily to verify compliance with equipment specifications. The Commissioning authority will provide in their review items unclear, missing, or areas that are not in conformance with Contract Documents.

C. The Contractor and Architect shall provide additional design narrative information requested by the Commissioning Authority, depending on the completeness of the Design Record documentation and sequences provided with the Specifications.

D. These submittals to the CxA do not constitute compliance for O&M manual documentation. The O&M manuals are the responsibility of the contractor, though the CxA will review and verify their content.

1.08 QUALITY ASSURANCE

A. Test Equipment.

1. All standard testing equipment required for the Contractor to perform installation, start-up and initial checkout and required performance testing shall be provided by the Contractor.
2. Special equipment, tools and instruments, only available from vendor, specific to a piece of equipment, required for testing equipment according to the Contract Documents shall be included in the base bid price to the Contractor and left on site, except for stand-alone datalogging equipment that may be used by the Commissioning Authority.
3. Datalogging equipment and software required to test the HVAC and mechanical equipment will be provided by the Commissioning Authority, but shall not become the property of the Owner.
4. Datalogging and test equipment required to test the electrical systems shall be provided by the Contractor but shall not become the property of the Owner. Instruments must be calibrated in accordance with the following frequency:
   a. Field Instruments: Analog, 6 months maximum, Digital, 12 months maximum
   b. Laboratory Instruments: 12 months

c. Leased specialty equipment: 12 months where accuracy is guaranteed by lessor.

5. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the specifications. If not otherwise given, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration within the past year to an accuracy of 0.5°F and a resolution of + or - 0.1°F. Pressure sensors shall have an accuracy of + or - 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals and when dropped or damaged. Calibration tags shall be affixed or certificates readily available.

PART 2 – PRODUCTS

2.01 PRODUCTS

NOT USED

PART 3 – EXECUTION

3.01 MEETINGS

A. Kick-off Meeting. Will be conducted in September 02, the Commissioning Authority will schedule, plan and conduct a commissioning kick-off meeting with the A/E, Contractor, Owner's representative, and the facility operator (if known). The commissioning plan, the overall commissioning process and general responsibilities of each team member, reporting and communication protocols and next steps will be discussed. Meeting minutes will be distributed to all parties by the Commissioning Authority.

B. Scoping Meeting: Will be conducted in January 03, the CxA will schedule, plan and conduct a commissioning scoping meeting with the entire commissioning team in attendance, including the controls, sheetmetal, electrical, mechanical, test, adjusting and balancing and other appropriate subcontractors and the facility operator or representative in attendance. One week prior to this meeting the updated commissioning Plan will be distributed to all members for their review. Meeting minutes will be distributed to all parties by the CxA within 2 weeks after the meeting. Information gathered from this meeting will allow the CxA to revise the *Commissioning Plan* to its "final" version, which will also be distributed to all parties.

C. Miscellaneous Meetings: Other meetings will be planned and conducted by the CxA as construction progresses. These meetings will cover coordination, deficiency resolution and planning issues with particular Subs. The CxA will plan these meetings and will minimize unnecessary time being spent by Subs.

3.02 CONSTRUCTION CHECKLISTS, START-UP, AND INITIAL CHECKOUT

A. The following procedures apply to all equipment and assemblies to be commissioned.

B. Static Elements. Systems or assemblies that are static in nature (*not* dynamic like mechanical or electrical systems) such as windows, envelope or roofs) may have very simplified construction checklists for installation and have no start-up requirements.

C. Construction Checklists. The Commissioning Authority develops new or adapts existing representative construction checklists and procedures for commissioned equipment and assemblies. A sample checklist is provided in Attachment 1 of the project manual.

D. Start-up and Initial Checkout Plan. The Contractor develops installation, start-up and initial checkout plans for equipment and assemblies with assistance from the Commissioning Authority. The primary role of the Commissioning Authority in this process is to ensure that there is written documentation that each of the manufacturer-recommended procedures have been completed and that the systems are ready for testing.

1. The start-up and initial checkout plan consists of:

    a. The manufacturer's installation instructions.

    b. The vendor's field checkout and start-up sheets.

    c. The construction checklists provided by the Commissioning Authority.

2. Manufacturer's Installation Instruction consist of the manufacturer's detailed start-up and checkout procedures copied from the O&M manual or shipped with the equipment. Each individual instructional procedure in these documents without a checkbox will have a line or box added in the margin for initialing when completed.

3. Vendor field checkout sheets consist of the manufacturer's field checkout and start-up sheets normally used by the manufacturer for start-up.

4. Construction Checklists consist of procedures and checks to ensure systems and assemblies are ready for operation and are provided by the Commissioning Authority to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks in the checklists and notes that trade on the checklist form.

    a. Calibrations. The construction checklists will contain requirements for calibrations. The Contractor is responsible to calibrate all field-installed temperature, relative humidity, CO, CO_2 and pressure sensors and gages, and all actuators (dampers and valves) on all equipment using methods approved by the Commissioning Authority. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated. Valve leak-by tests shall be conducted by the Contractor when shown on a construction checklist. All procedures used shall be fully documented on the construction checklists or other suitable forms, clearly referencing the procedures followed and written documentation of initial, intermediate and final results.

b. Point-to-point Checkout. Included in the checkout plan will be a point-to-point checkout of each control point tied to a central control system. Each point will be verified to be commanding, reporting and controlling according to its intended purpose. For each output, commands will be initiated and verified to be functioning by visually observing and documenting the status of the controlled device in the field (e.g., command lights or sound off, command cooling coil valve to full open, or command heating water pump off). For each input, the system or conditions will be perturbed to initiate the input response being tested and the response in the control system observed and recorded (e.g., high duct static pressure alarm).

5. The Contractor compiles the full installation, start-up and initial checkout plan and provides a signature block at the beginning of the plan covering the entire plan execution.

6. At the Commissioning Authority's request, for complex systems or assemblies, the Contractor shall develop a custom narrative description of the proposed start-up or concealment process taking into account interactions and impacts on other systems, construction coordination and scheduling, indoor air quality, system cleanliness, equipment warranty, etc.

7. The Contractor submits the full plan to the Commissioning Authority for review and approval. The Construction Manager may also review selected start-up plans.

E. Execution of Construction Checklists and Start-up.

1. Each piece of equipment or assembly being commissioned receives full construction checkout by the Contractor following the approved plan and forms. No sampling strategies are used. Only individuals that have direct knowledge and witnessed that a line item task on the construction checklist was actually performed shall initial or check that item off. It is not acceptable for non-witnessing supervisors to fill out the forms.

2. For dynamic mechanical or electrical equipment, the Contractor shall complete the pre-start procedures in the plan prior to starting equipment. For static assemblies the contractor shall complete pre-concealment procedures before concealing any assembly. The Contractor shall notify the Commissioning Authority at least five days in advance of any equipment start-up or assembly concealment, providing the Commissioning Authority a copy of the pre-start/pre-concealment sections of the installation and start-up plan at start-up.

3. The Commissioning Authority shall observe installation, start-up and checkout of selected systems and assemblies. Procedures on the plans and checklists will be spot-checked by the Commissioning Authority prior to testing.

4. The Contractor and vendors shall execute start-up or concealment and provide the Commissioning Authority with a signed and dated copy of the completed construction checklists and installation and start-up documentation. The Contractor shall clearly note any items that have not been completed and the plan for their completion.

5. The Construction Checklist and other procedures from the plan for a given system or assembly must be successfully completed prior to formal performance testing of the equipment.

6. The Commissioning Authority reviews the documentation and identifies incomplete areas.

7. The Contractor shall correct all areas that are deficient or incomplete in the checklists in a timely manner.

3.03 TESTING

A. This sub-section applies to all commissioning testing for all divisions.

B. The Contractor shall be responsible to fully test all systems and assemblies according to the specifications. The Commissioning Authority will direct, witness and document the testing. The Contractor shall execute the tests.

C. Testing Requirements. The testing requirements for Building Envelop are found in Section 1811. The testing requirements for HVAC and mechanical systems and equipment are found in sections 01812. Testing requirements for the electrical systems and equipment are found in 01813. The Commissioning Authority shall develop documentation forms for the HVAC and mechanical equipment testing during the construction phase of the project after approved equipment and control system shop drawings are available.

D. <u>Objectives and Scope.</u>

1. The objective of performance testing is to demonstrate that each system is operating according to the documented Owner Objectives and Contract Documents. For dynamic systems, testing facilitates bringing the systems from a state of initial operation to full dynamic operation. For static elements, testing verifies the performance of the assembly in its installed state under conditions specified in the testing requirements. Additionally, during the testing process, areas of deficient performance are identified and corrected.

2. In general testing shall include testing each sequence in the sequence of operations, and other significant modes, sequences and control strategies not mentioned in the written sequences; including, but not limited to startup, shutdown, unoccupied and manual modes, modulation up and down the unit's range of capacity, power failure, alarms, component staging and backup upon failure, interlocks with other equipment, and sensor and actuator

calibrations. All interlocks and interactions between systems shall be tested. All larger equipment will be individually tested. Like units or assemblies that are numerous (many smaller rooftop packaged units, air terminal units, exhaust fans, windows, etc.) may have an appropriate sampling strategy applied. Heating equipment must be tested appropriately during winter and air conditioning equipment must be tested appropriately during summer to demonstrate performance under near-design conditions.

E. Development of Performance Test Procedures. The Commissioning Authority obtains needed documentation: equipment specifications, testing requirements, O&M manuals, start-up and initial start-up instructions, sequences of operation, and mechanical, electrical and control drawings and writes detailed step-by-step testing procedures to comply with the testing requirements. Prior to execution, the Commissioning Authority will provide a copy of the test procedures to the Contractor who shall review the tests for feasibility, safety, equipment and warranty protection.

F. Test Procedure Format. A sample test form is provided as an attachment to the bid documents. The test procedure forms developed by the Commissioning Authority shall include (but not be limited to) the following information:

1. System and equipment or component name(s)
2. Equipment location and ID number
3. Unique test ID number and reference to unique construction checklist and start-up documentation ID numbers for the piece of equipment
4. Date
5. Project name
6. Participating parties
7. A copy of the specification section describing the test requirements
8. A copy of the specific sequence of operations or other specified parameters being verified
9. Formulas used in any calculations
10. Required pre-test field measurements
11. Instructions for setting up the test.
12. Special cautions, alarm limits, etc.
13. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format
14. Acceptance criteria of proper performance with a Yes / No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
15. A section for comments
16. Signatures and date block for the Commissioning Authority

G. <u>Performance Test Methods.</u>

1. Testing and verification for most dynamic equipment shall be achieved by an appropriate combination of manual testing (persons manipulate the equipment and observe its function) or by monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone dataloggers. The testing requirements sections of the specification describe which methods shall be used for each test. The Commissioning Authority may substitute specified methods or require an additional method to be executed, other than what was specified, with the approval of the Contracting Officer.
2. <u>Simulated Conditions.</u> Simulating conditions other than by overwriting a value shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
3. <u>Overwritten Values.</u> Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable. e.g., for the above case, by heating the outside air sensor with a hair blower rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.
4. <u>Simulated Signals.</u> Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.
5. <u>Altering Setpoints.</u> Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55F, when the outside air temperature is above 55F, temporarily change the lockout setpoint to be 2F above the current outside air temperature.
6. <u>Indirect Indicators.</u> Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification is completed during construction checklists and calibrations.
7. <u>Setup.</u> Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Contractor shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Contractor shall return all affected building

equipment and systems, due to these temporary modifications, to their pre-test condition.

8. Sampling. Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. Significant application differences and significant sequence of operation differences in otherwise identical equipment invalidates their common identity. A small size or capacity difference, alone, does not constitute a difference. The specific recommended sampling rates are specified with the testing requirements. It is noted that no sampling by the contractor is allowed in construction checklist execution.

9. Testing Order. In general, testing is conducted after construction checklists are complete and start-up has been satisfactorily completed. The control system is sufficiently tested and approved by the Commissioning Authority before it is used for testing, adjusting and balancing or to verify performance of other components or systems. The air balancing and water balancing is completed and debugged before testing of air-related or water-related equipment or systems. Testing generally proceeds from components to su-systems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is verified.

10. Trend Logs and Monitoring. Trend logs required in the testing requirements will be set up and executed by the Contractor and provided to and analyzed by the Commissioning Authority. Monitoring using dataloggers will be conducted by the Commissioning Authority. Trend logs and monitoring are conducted after manual testing and subsequent trouble-shooting are complete and systems are in normal operation without frequent service shutdowns, etc.

G. Problem Solving. The burden of problem solving is on the Contractor and the Architect, though the Commissioning Authority may recommend solutions to problems found.

3.5 NON-CONFORMANCE AND APPROVAL OF TESTS

A. Non-Conformance.

1. The Commissioning Authority will record the results of the tests and trend logs or monitoring on the procedure or test form. All deficiencies or non-conformance issues shall be recorded on a master Issues Log kept by the Commissioning Authority and reported directly to the Contracting Officer within two days of occurrence or sooner when scheduling and coordination require it. The Contracting Officer and Contractor, in consultation with the Architect when necessary, will determine the

responsible party and a suitable plan for resolution. The Commissioning Authority is notified of the resolution and documents it in the Issues Log.

2. The Commissioning Authority is notified when the issue has been resolved and reschedules the test and the test is repeated.
3. Corrections of minor issues identified may be made during the tests at the discretion of the Commissioning Authority and with the issue and resolution documented in the Issues Log.
4. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the Commissioning Authority will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so at the request of the Contracting Officer.
5. Cost of Retesting.
   a. For a deficiency identified, not related to any construction checklist or start-up fault, the following shall apply: The Commissioning Authority and GC will direct the retesting of the equipment once at no "charge" to the Contractor for their time. However, the Commissioning Authority's and GC's time for a second retest will be charged to the Contractor.
   b. The time for the Commissioning Authority and GC to direct any retesting required because a specific *construction* checklist or start-up test item, reported to have been successfully completed, but determined during testing to be faulty, will be charged to the Contractor.
6. The Contractor shall respond in writing to the Commissioning Authority and PM at least as often as commissioning meetings are being scheduled concerning the status of each outstanding issue identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.
7. Any required retesting by the Contractor shall not be considered a justified reason for a claim of delay or for a time extension by the Contractor.

B. <u>Failure Due to Manufacturer Defect.</u> For identical or near-identical components numbering more than ten (e.g., terminal units, diffusers, traps, valves, etc.): if 10%, or three, whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively) due to manufacturing defect, not allowing it to meet its submitted performance specification, all identical units may be considered unacceptable by the PM. In such case, the Contractor shall provide the PM with the following:

1. Within one week of notification from the PM, the Contractor or manufacturer's representative shall examine all other identical units

making a record of the findings. The findings shall be provided to the PM and GC within two weeks of the original notice.

2. Within two weeks of the original notification, the Contractor or manufacturer shall provide a signed and dated, written explanation of the problem, cause of failures, etc. and all proposed solutions which shall include full equipment submittals. The proposed solutions shall not significantly exceed the specification requirements of the original installation.
3. The PM will determine whether a replacement of all identical units or a repair is acceptable.
4. Two examples of the proposed solution will be installed by the Contractor and the PM, GC, CxA will be allowed to test the installations for up to one week, upon which the PM will decide whether to accept the solution.
5. Upon acceptance, the Contractor and/or manufacturer shall replace or repair all identical items, at their expense and extend the warranty accordingly, if the original equipment warranty had begun. The replacement/repair work shall proceed with reasonable speed beginning within one week from when parts can be obtained.

C. Approval and Acceptance. The Commissioning Authority notes each satisfactorily demonstrated function on the test form. However, formal approval of an entire test form is not normally given. Approval or acceptance of a system is indicated after all testing and monitoring is complete and there are no outstanding issues for that equipment or assembly in the Commissioning Authority's Issues Log.

3.06 DEFERRED TESTING

A. Unforeseen Deferred Tests. If any check or test cannot be completed due to the building structure, required occupancy condition or other deficiency, execution of checklists and testing may be delayed upon approval of the PM.

B. Seasonal Testing. During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) specified in the testing requirements shall be completed as part of this contract. The Commissioning Authority shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the Contractor, with facilities staff and the Commissioning Authority witnessing. The Contractor shall make needed final adjustments to the O&M manuals and as-builts due to the testing results.

C. Scheduled Deferred Tests. Specific tests such as thermography of the electrical distribution system are less meaningful in an unoccupied or partially occupied building. As such tests requiring occupancy loads will be scheduled in accordance to meeting desired occupancy conditions.

3.06 DOCUMENTATION

A. Commissioning Plan. The Commissioning Plan is defined in this section and follows the process outlined in the specifications. The Commissioning Authority develops and updates the commissioning plan as construction progresses. The Specifications will take precedence over the Commissioning Plan.

B. Schedule. The PM and Contractor work with the Commissioning Authority using established protocols to schedule the commissioning activities. The PM and Contractor shall integrate all commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process. As construction progresses, more detailed commissioning schedules shall be developed. The Contractor shall provide a minimum of two weeks notice prior to the date of testing to the GC and Commissioning Authority. In addition, the Commissioning Authority and GC shall be notified 36 hours in advance when tests are canceled or rescheduled. The Contractor shall reimburse the Contracting GC and Commissioning Authority for labor and travel costs for a test that has either been canceled or rescheduled with out required notice. The Contractor shall also reimburse the Contracting Officer and Commissioning Authority for costs when a scheduled test cannot be completed due to failure of the Contractor to properly prepare for the test, including but not limited to:

1. Failure to schedule the test with all parties required to perform the test or with regulatory authorities required to witness the test.
2. Failure to complete pre-start or start-up procedures or other work required as a prerequisite for execution of the test.
3. Failure to have in place test equipment, support equipment, instrumentation, permits, or other ancillary equipment or systems required for successful execution of the test.

C. Reporting and Documentation by the Commissioning Authority

1. The Commissioning Authority will provide regular reports of all issues and progress directly to the PM with increasing frequency as construction and commissioning progresses. Issues that are in the schedule critical path or which significantly affect budget or building performance will be reported within 2 days of identification.
2. The Commissioning Authority will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.
3. The Commissioning Authority shall witness and document the results of all performance tests using the specific procedural forms developed for

that purpose. The Commissioning Authority will include the filled out forms in the Commissioning Record.

4. <u>Systems Manual.</u> A Systems Manual will be compiled by the Commissioning Authority. See details below.

5. <u>Commissioning Record.</u> The Commissioning Authority is responsible to compile, organize and index commissioning data by equipment and assembly into labeled, indexed and tabbed, three-ring binders and deliver it to the PM, to be included with the O&M manuals. Three copies of the manuals will be provided. The record will contain for all systems and assemblies together: the Summary Report, Issues Log, Commissioning Plan, progress reports, submittal reviews, construction observation reports, O&M manual reviews, summary training record, testing schedule. Then for each system or assembly: the sequence of operation, construction checklist, start-up report, functional and regulatory test and inspection records, training record. And finally, the indexed and fully labeled trend log analysis of all systems.

6. <u>Summary Report.</u> The summary commissioning report shall include an executive summary, list of participants and roles, brief building description, overview of commissioning and testing scope and a general description of testing and verification methods. For each piece of commissioned equipment or assembly, the report should contain the disposition of the Commissioning Authority regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas: 1) Meeting the equipment specifications, 2) Installation, 3, Functional performance and efficiency, 4) Equipment O&M manual documentation , and 5) Operator training. All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. shall also be listed. Each non-compliance issue shall be referenced to the specific test, inspection, trend log, etc. where the deficiency is documented. The performance and efficiency section for each piece of equipment shall include a brief description of the verification method used (manual testing, BAS trend logs, data loggers, etc.) and include observations and conclusions from the testing.

D. Systems Manual. The Commissioning Authority (CxA) will compile a Systems Manual. The following components of the manual are organized and indexed by system into one compilation. The responsibility of the Contractor and other parties in the System Manual development are given in brackets.

1. Design Record. The Design Record for each system or assembly included in the Systems Manual, consists of:

a. Owner Requirements and Objectives (see Definitions) [by Owner]

b. Design Basis (see Definitions) [by Architect]

c. Design Narrative (see Definitions) [by Architect]

d. Performance Metrics, if developed (see Definitions) [by CxA, if in scope]

2. Fire and life safety and emergency power criteria including a general strategy narrative, detailed sequences and an HVAC fire and emergency power response matrix. [format by CxA and content by Contractor and Architect]

4. Seasonal start-up and shutdown, manual and restart operation procedures. [by Contractor]

5. Complete as-built control drawings with points list, valve schedules, schematics, control system architecture and full sequences of operation. [by Contractor]

6. A description of and rationale for all energy saving features and strategies with operating instructions and caveats about their function and maintenance relative to energy use. [by Designer]

7. Recommendations for recalibration frequency of sensors and actuators by type and use. [by CxA]

8. Plans for continuous commissioning or recommended frequency for recommissioning by equipment type with reference to tests conducted during initial commissioning. [by CxA]

9. Description of the primary recommended standard trend logs in the control system that will assist in maintaining comfort, energy efficiency and system control. This will include sample plots with explanations of what to look for in the graphs. [by CxA]

10. Specific recommendations regarding seasonal operational issues that affect energy use. [by CxA]

11. A list of all user adjustable setpoints and reset schedules with a discussion of the purpose of each and the range of reasonable adjustments with energy implications. Include a schedule frequency to review the various setpoints and reset schedules to ensure they are at current relevant and efficient values. [by CxA]

12. A list of time of day schedules [by Contractor] and a schedule frequency to review them for relevance and efficiency [by CxA].

13. Guidelines for establishing and tracking benchmarks for whole building energy use and primary plant equipment efficiencies. [by CxA]

14. Guidelines for ensuring that future renovations and equipment upgrades won't result in decreased energy efficiency and maintaining the final design intent. [by CxA]

15. A list of diagnostic tools, with a description of their use, that will assist facility staff in operating equipment more efficiently. [by CxA]

16. Systems to be included in the Systems Manual are: all the systems listed in this section as being commissioned.

17. The units used in the manual will be English with parenthetical reference to metric according to details given in this section.

E. <u>O&M Documentation Review.</u> Prior to substantial completion, the Commissioning Authority shall review the O&M manuals, documentation and redline as-builts for systems that were commissioned to verify compliance with the Specifications. The Commissioning Authority will communicate deficiencies in the manuals to the Construction Manager, Contracting Officer or the Architect, as requested. Upon a successful review of the corrections, the Commissioning Authority recommends approval and acceptance of these sections of the O&M manuals. The Commissioning Authority also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated. This work does not supersede the Architect's review of the O&M manuals according to their contract.

END OF SECTION 01810

Annex L.4: Example Specification 01810 - General Requirements for a Recent Building

Commentary: This sub-annex provides and example general requirements specification for Section 01810. This section includes general requirements for all building systems, including the building exterior enclosure (envelope). This example is from a relatively recent project but may specify more stringent requirements in some places than those of Guideline 0-2005, or this Guideline 3-2006. For example, this example specifies “ensure” in several locations; whereas ensuring results is not a requirement of these guidelines. Although it is desirable that a specific requirement is achieved, the commissioning process defined in these guidelines does not ensure that every outcome is absolutely achieved. The commissioning process is a quality process that uses a quality team and leader to verify that those responsible for a specific task are achieving (and ensuring to the best of accepted practice, as it is their responsibility) the owner’s project requirements. The scope and format of this example should be very useful to those developing commissioning process specifications. However, caution should be taken not to use the language in the example verbatim relative to such items as “ensure” or “deficiency” in order to maintain consistency with the level of requirements of Guidelines 0-2005 and 3-2006.

Credits: This example general requirements specification has been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

Annex L.5:
Example Specification 01811 of
Fenestration System Testing Requirements
for A Recent Building

Commentary: This sub-annex provides and example general requirements specification for Section 01811. This section includes specification for fenestration system testing requirements for a recent project.

Credits: This example of specifications for fenestration systems testing for a recent project has been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

SECTION 01811
FENESTRATION SYSTEM TESTING REQUIREMENTS

PART 1 GENERAL

1.01 SUMMARY

A. This section specifies the testing requirements for Divisions 3, 4, 7 and 8 systems. From these requirements, the CxA shall develop step-by-step procedures to be executed by the Contractor, independent testing agency, and the CxA. The general testing process, requirements and test method definitions are described in Section 01810. The test requirements for each configuration of the building envelope assembly contain the following:

1. The contractors/testing agency responsible to execute the tests, under the direction of the CxA.
2. A list of the integral components being tested.
3. Checklists associated with the components.
4. Functions to be tested.
5. Required conditions of the test.
6. Special procedures.
7. Required methods of testing.
8. Required monitoring.
9. Acceptance criteria.
10. Sampling strategies allowed.

1.02 PREREQUISITES

A. Test results from independent testing laboratory per Architects requirements contained in this project manual.

B. The construction checklist (CK) items shall be listed on a written form and are required to be completed by the contractor and checked off by the CxA prior to testing. Checklists are generally typical forms used by the contractors to track completion of their work plus information required by the CxA.

C. Construction checklists (CK) contain items for Division 3, 4, 7 and 8 contractors to perform. On each checklist, a column is provided that for the responsible trade to filled out. Those executing the checklists are only responsible to perform items that apply to the specific application at hand. These checklists do not take the place of the manufacturer's recommended checkout and installation procedures or reporting. Some checklist procedures may be redundant of some checkout procedures that will be documented on typical factory field checkout sheets. Double documenting is required in those cases.

D. Refer to Section 01810 for additional requirements regarding construction checklists, installation and initial checkout. Items that do not apply should be noted along with the reasons on the form. Contractors' assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off. “Contr.” column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CxA = commissioning authority, GC = general contractor, UMC = masonry contractor, LVC = limestone veneer contractor, SMC = sheet metal contractor, SC = sealant contractor, GLC = glazing contractor.

E. The CK contained in Attachment 1a is a **sample**. Job-specific CKs will be developed by the CxA and provided to the GC for distribution to the Subs. Subs shall complete CKs as sections of work are completed and provide the completed checklist to the CxA through the GC. Completion of the CK is notification to the GC and CxA that the specific area of work is complete and ready for testing.

F. Suggested Numbering Key For Commissioning Procedures

The checklists, tests, documentation and training use the following identification numbering:

At the beginning of the identification number is a text abbreviation for the following:

Document or Event Abbreviations

DOC	=	Documentation
CK	=	Construction Checklist
IP	=	Installation Plan
T	=	Testing
R	=	Review
TR	=	Training Record

Numbering Key

CK-0102.3: The first four digits uniquely identify the piece of equipment to the component level. The first 2 digits are the System Type, the second 2 digits are an arbitrary component number (not necessarily the same as the specified ID number). The number after the decimal is the test number. For example, CK-0102.3 = Construction Checklist 3 of the precast to precast joint, component number 2 (e.g., 0302.3 = Precast component #2, CK #3, because precast is system Type 01). The component number of 00 means “general” or “all” components, as with the entire system. All tests, procedures, training and records should have the same first 4 digits for any given component.

Another example. If there were only 1 aluminum window type, then tests would be numbered CK-0600.1, 0600.2, etc. If there were 2 aluminum window types: CK-0601.1, 0601.2, etc and 0602.1, .2 etc.

An *example* of the number system follows:

0100	Architectural Precast Concrete	0200	Sheet Metal Flashing & Trim
	0101 Precast Panel		
	0102 Precast Panel to Precast Panel Joint	0300	Joint Sealants
	0103 Precast Panel to Stucco Wall Joint		
	0104 Precast Panel to Aluminum Window Joint	0400	Composite Metal Panels
	0105 Precast Panel to Curtain Wall Joint		
	0106 Precast Panel to Sheet Metal Flashing Joint	0500	Aluminum Windows
			etc…

<u>Numbers for Primary System Types and Components</u>

01 Architectural precast concrete

02 Sheet metal flashing & trim

03 Joint sealants

04 Composite metal panels

05 Aluminum windows

06 Glazing

07 Glazed aluminum curtain walls

08 Flat roof

09 Sloped roof

G.

PART 2 PRODUCTS

NOT USED

PART 3 EXECUTION

3.01 Testing of Mock-Ups of Exterior Wall Assembly

A. Parties Responsible to Execute Testing

1. Independent testing agency approved by the Owner or Contractor under CxA supervision.
2. CxA to witness, direct and document testing.
3. Contractor financially responsible for additional testing cost if work requires retesting.

B. Integral Components or Assemblies Being Tested

1. Limestone Veneer
2. Sheet Metal Flashing & Trim
3. Joint Sealants
4. Glazing

C. Prerequisites: The applicable construction checklist items shall be complete and signed by the Contractor's employee having direct knowledge that work is completed and sealants are cured as necessary for testing prior to testing. The CxA will also spot-check misc. items on the CK previously completed by the installer, before the beginning of testing.

D. Functions Required To Be Tested and Test Methods

1. A minimum of three separate wall assemblies will be tested.
2. The following testing requirements in Table 1 are an addition to and do not replace any testing requirements elsewhere in the project manual.

3.02 Random Testing of Exterior Wall Assemblies

A. Parties Responsible to Execute Testing

1. Independent testing agency approved by the Owner or Contractor under CxA supervision.
2. CxA to witness, direct and document testing.
3. Contractor financially responsible for additional testing cost if work requires retesting.

B. Integral Components or Assemblies Being Tested

1. Limestone Veneer
2. Sheet Metal Flashing & Trim
3. Joint Sealants
4. Glazing

C. Prerequisites: The applicable construction checklist items shall be complete and signed by the Contractor's employee having direct knowledge that work is completed and sealants are cured as necessary for testing prior to testing. The CxA will also spot-check misc. items on the CK previously completed by the installer, before the beginning of testing.

D. Functions Required To Be Tested and Test Methods

1. A minimum of 10% of window assemblies and adjacent wall assemblies will be tested including sections previously tested as described in this section.

2. The following testing requirements in Table 1 are an addition to and do not replace any testing requirements elsewhere in the project manual.

TABLE 1

Function / Mode	**Test Method** Manual, Monitoring, Either or Both[3]	**Required Seasonal Test**[1]
General 1. Sections of exterior wall will be constructed in place and serve as mockups and may remain as part of the installation. The mockups will serve to perfect installation practices prior to the construction of the exterior walls. The mockups shall contain each component of the exterior wall assembly as it will be installed on the remaining building exterior. The mockup shall be tested as an assembly focusing on intersections between assembly components using AAMA 501.2 test method.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Random testing of building exterior using AAMA 501.2 test method as directed by the CxA.	Manual	

Function / Mode	Test Method Manual, Monitoring, Either or Both[3]	Required Seasonal Test[1]
3. Each window model or curtain wall configuration scheduled for installation in the mockups shall be tested and passed by an independent laboratory prior to installation in the mockups in accordance with ASTM E283 test for air leakage. The ASTM E 283 test shall be conducted at an air pressure difference of 6.24 lbs/ft². The maximum allowable rate of air leakage must not exceed .06 ft³/min./ft².	Manual	
4 Each window model or curtain wall configuration scheduled for installation in the mockups shall be tested and passed by an independent laboratory prior to installation in the mockups in accordance with ASTM E331 test for water penetration. The ASTM E 331 test shall be conducted at an air pressure difference of 12.0 lbs/ft². There shall be no water leakage as defined under laboratory specification section of AAMA 501-94 at this pressure difference.	Manual	
5 Each window model or curtain wall configuration scheduled for installation in the mockups shall be tested and passed by an independent laboratory prior to installation in the mockups in accordance with ASTM E330 test for structural performance. No failure or permanent deflection in excess of 0.2 percent of any members span after removing the imposed load for a positive and negative design wind pressure of 120 lbf/sq. ft.	Manual	

[1]Refer to Special Procedures

3. Special Procedures

a. Exterior Wall Testing: A full-sized mock-up of each type of masonry, limestone veneer, wood windows, and glazing will be tested in the installation configuration detailed in the construction documents. These assembles will be used to establish the installation practices that will be maintained by the contractors during the assembly of the exterior wall system. Concerns identified during the testing of the mock-ups must be resolved before proceeding with installation of the fenestration system. Testing must be witnessed by the CxA.

4. Acceptance Criteria

   a. For the assemblies tested no moisture intrusion observed through the assembly.

5. Sampling Strategy for Identical Assemblies

   a. All identical assemblies shall be randomly tested per the above tests as directed by the CxA. Ten percent (10%) of the fenestration system will be tested using the AAMA 501.2 test method. In no case test less than three locations for each assembly type. If failure is observed in the first samples tested, an additional 10% of the fenestration system will be tested fully at the responsible contractor's expense.

END OF SECTION 01811

Annex M: Construction Checklists

Commentary: This annex is intended to provide information about checklists about the building exterior enclosure that are available form various sources. A number of these checklists are protected by copyright, so we are not re-producing them here. For such checklists we provide citations for the reader to use to obtain the checklists from the organizations that have published them.

In addition, we are including in sub-annexes selected pre-functional checklists that have been developed by members of the GL 3-2006 development committee. When applying the content provided in these sub-annexes the reader is encouraged to apply the checklist formats provided in Guideline 0-2005, Annex M. There are related test sub-annexes in Annex U below.

There are 3 sub-annexes to this annex that contain example construction checklists:

- M.1 – This sub-annex consists of 10 Construction & Industry Checklists compiled over time by McCarthy Building Companies, Inc. and assembled and formatted for this document by Bill Nash of McCarthy. These include:

  (1) Construction & Industry Checklist for *Waterproofing*, *07100*, Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (2) Construction & Industry Checklist for *EIFS*, *07240*, Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (3) Construction & Industry Checklist for *Commercial Low Slope Roofing Systems, 07500,* Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (4) Construction & Industry Checklist for *Flashing and Sheet Metal, 07600,* Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (5) Construction & Industry Checklist for *Joint Sealers, 07900,* Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (6) Construction & Industry Checklist for *Entrances and Storefronts, 08400,* Division 8, Doors and Windows, Jan. 1, 2002.

  (7) Construction & Industry Checklist for *Windows, 08500,* Division 8, Doors and Windows, Jan. 1, 2002.

  (8) Construction & Industry Checklist for *Skylights, 08600*, Division 8, Doors and Windows, Jan. 1, 2002.

  (9) Construction & Industry Checklist for *Glazing, 08800*, Division 8, Doors and Windows, Jan. 1, 2002.

  (10) Construction & Industry Checklist for *Glazed Curtain Walls, 08900*, Division 8, Doors and Windows, Jan. 1, 2002.

- M.2 – Pre-functional Checklist for Building Envelope (Exterior Enclosure) System.
- M.3 – Pre-functional Checklist for Windows and Doors.

Credits: The following persons and organizations have provided materials for this annex and its sub-annexes:

- o Sub-annex M.1 has been provided by Bill Nash of McCarthy Building Companies, Inc.
- o Sub-annexes M.2 and M.3 have been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

M-1 Citations of Available Construction Checklists

The following is a list of citations of available construction checklists from other sources, organized by type of element of the building exterior enclosure.

Good Painting Practice: SSPC Painting Manual. The Society for Protective Coatings. Vol. 1, 4th ed. P. 545-551.

Manual for Inspection and Maintenance of Build-Up and Modified Bitumen Roof Systems: A Guide for Building Owners. Asphalt Roofing Manufacturers Association and National Roofing Contractors Association. P. 16-22.

Masonry Inspection Checklist. TMS Construction Practices Committee. The Masonry Society, Boulder, CO. 2004.

Portland Cement Plaster Stucco: Resource Guide. Northwest Wall & Ceiling Bureau. P. 178-183.

Annex M.1:
Ten Example Construction & Industry Checklists

Commentary: This sub-annex provides 10 examples of Construction & Industry Checklists compiled over time by McCarthy Building Companies, Inc. and assembled and formatted for this document by Bill Nash of McCarthy. The 10 example checklists are intended to provide generic resources that the user may adapt to fit the needs of specific projects. In developing checklists for specific projects the user is encouraged to use the formats recommended in ASHRAE Guideline 0-2005.

The 10 generic checklists provided in this sub-annex are:

1. Construction & Industry Checklist for *Waterproofing*, *07100*, Division 7, Thermal and Moisture Protection.
2. Construction & Industry Checklist for *EIFS*, *07240*, Division 7, Thermal and Moisture Protection.
3. Construction & Industry Checklist for *Commercial Low Slope Roofing Systems, 07500,* Division 7, Thermal and Moisture Protection.
4. Construction & Industry Checklist for *Flashing and Sheet Metal, 07600,* Division 7, Thermal and Moisture Protection.
5. Construction & Industry Checklist for *Joint Sealers, 07900,* Division 7, Thermal and Moisture Protection.
6. Construction & Industry Checklist for *Entrances and Storefronts, 08400,* Division 8, Doors and Windows.
7. Construction & Industry Checklist for *Windows, 08500,* Division 8, Doors and Windows.
8. Construction & Industry Checklist for *Skylights, 08600*, Division 8, Doors and Windows.
9. Construction & Industry Checklist for *Glazing, 08800*, Division 8, Doors and Windows.
10. Construction & Industry Checklist for *Glazed Curtain Walls, 08900*, Division 8, Doors and Windows.

Credits: Bill Nash of McCarthy Building Companies, Inc. had provided materials for this sub-annex including those adapted from the following sources:

7100 – Waterproofing – Western Waterproofing

7240 – Exterior Insulation Finish System (EIFS) - Robert Thomas

7500 – Roofing – National Roofing Contractors Association - NRCA

8400,8500,8800,8900 – American Architectural Manufacturers Association - AAMA

M.1-1 *Waterproofing Checklist*, *07100*

(*Construction & Industry Checklist for Waterproofing, 07100, Division 7, Thermal and Moisture Protection*)

1. Verify product specified is appropriate to site conditions.
2. Verify subcontractor is authorized by manufacturer to apply product.
3. Verify exposed areas have been masked to protect adjacent work and property.
4. Verify that acceptable weather conditions are present for application (above 40 deg F, not damp or foggy, depending on material used).
5. Verify surfaces are primed, if required.
6. Provide applicator with substrates that are free of standing water, dirt and debris, loose material, voids and protrusions or deformations, which may inhibit application or performance of waterproofing.
7. If waterproofing application will be setup on bare ground, provide sub grades that are stable, smoothed and compacted to minimum 85 percent modified proctor density.
8. If waterproofing will be installed on earth retaining system, fill gaps and voids in earth retaining system to conform to waterproofing manufacturer's requirements; remove nails in wood lagging.
9. If waterproofing will be installed on concrete and/or masonry, provide substrates that are free of voids deeper than 3/8" and free of surface protrusions more than 1/4" above the surface.
10. If waterproofing will be installed on concrete footings, provide wood float or better finish to surfaces scheduled to receive the vapor-protective waterproofing.
11. If waterproofing will include bentonite water stop strips, provide concrete surfaces as required for that installation.
12. Verify laps between membrane sheets are consistent with approved details (flashings, changes of plane in membrane showing overlap, etcetera).
13. Verify joinery between each day's work is adequate.
14. Verify that interstitial moisture is not present.
15. Verify that stored materials are protected against moisture.
16. Verify proper fasteners and adhesives are used.
17. Verify that membrane is applied smooth without buckles or "fish mouths".
18. Rigidly install penetrations of vapor-protective waterproofing for detailing procedures.
19. Take appropriate protective measures to ensure that finished work is not penetrated or damaged by other trades.
20. Verify that proper ventilation is being maintained during application of waterproofing utilizing chemicals and solvents.
21. Verify that subcontractor has properly disposed of excess materials in compliance with EPA and OSHA requirements.

22. Ensure pipes, ducts, conduits, and other items penetrating membrane are watertight.
23. Verify proper coverage and quantities of materials such as mil thickness.
24. Verify protective covering is provided and installed as required and backfilling takes place immediately, and the covering remains in place during backfilling.
25. Perform field water testing of the completed installation wall penetrations prior to backfill operations

M.1-2 EIFS Checklist, 07240

(Construction & Industry Checklist for EIFS, 07240, Division 7, Thermal and Moisture Protection)

1. Verify flashing has been installed at windows- head, sills, jambs, doors, roof, louvers, and parapets.

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2. Mesh may not be stapled. It is to be embedded in the PB base coat.
3. Must tent and heat if under 40 degrees for 24 hours. Check the manufacturers recommendations from specific systems and their individual product components. Proper storage of materials is critical.
4. Must install the expansion joints out to edge, you do not want them built over.
5. Every 75 lineal feet needs a control joint.
6. Back wrapping is required for all EIFS.
7. EIFS must not be installed below grade.
8. Ganged penetrations are preferred in lieu of multiple close-together penetrations that will weaken the EIFS.
9. Warranty must be identified in bid documents.
10. Expansion joints are required at all floor lines.
    - Sealant joints must be made to the base coat, never to the finish topcoat.
    - Materials for a wall system must be sourced from an assembly of a system with specifically lab-tested materials. Materials must be a tested system.

The checklist below is for use while installing a Type PB EIFS. Its purpose is to alert you to key issues that need to be looked-into while the work is being done.

General:

11. Coverage rates for materials.
12. Safe access to wall (scaffold, swing stage).

13. Weather during entire application period.
14. Availability of water, electrical power.
15. Coordination with other trades (windows, sealants, masonry, metal panels, roofing.)
16. Warranty issues.
17. Construct a mock up of the EIFS wall assembly complete with flashings, penetrations, terminations and water test

Substrate:

18. Type
19. Flatness and "straightening" of surface.
20. Structural soundness and general condition.
21. Presence of surface coatings and removal thereof.
22. Removal of projections, existing windows, utilities, and so on.

EPS:

23. Density, bagged shipped.
24. Board size and thickness (2x4). Rasping required prior to base coat application.
25. Flatness and squareness.
26. Fusion of beads.
27. Approved EPS supplier
28. Third party listing and labels.
29. Patterns for making foam shapes.

Attachment Adhesive:

30. Type
31. Condition
32. Type and condition of Portland Cement. Premixed material is preferred; field mixing is not an acceptable method.

Preparing Attachment Adhesive:

33. Tools and mixing technique.
34. Proper cement/adhesive ratio.

Putting Adhesive on EPS:

35. Pattern
36. Quantity

Attaching EPS:

37. Planeness of outside surface.
38. Tightly abutted EPS joints are a requirement.
39. Adhesive or basecoat between board ends is not permitted.
40. "L"-shaped pieces at corners of openings, per EIMA.
41. Running bond pattern of EPS boards per EIMA.
42. Interlocking of EPS boards at corners per installation procedures per installation procedure/ EIMA.
43. Bonding of foam shapes to the substrate.

Curing of Attachment Adhesive:

44. Temperature, weather, and protection.

Adhesive:

45. Type and condition.
46. Mixing tools and technique.
47. Maintenance of adhesive/cement ratios.

Inspection of Surface of EPS:

48. Repair damage, if any.
49. Gaps between board ends are not permitted. Must be properly filled with EPs <u>not</u> base coat.
50. Plane-ness/sanding, rasping is a must prior to base coat installation of EPS surface.

Preparation of EPS for Base Coat:

51. Routing of aesthetic grooves.
52. Adding foam shapes to EPS.
53. Adding holes for penetrations.
54. Adding drip grooves and flashings.

Reinforcing Mesh:

55. Type, weight and coating per manufacturer and project specifications.
56. Cutting to size, proper minimum lap.per EIFS manufacturer

Applying Base Coat:

57. Temperature and weather conditions.

58. Thickness and full embedment of mesh. Mesh should not be visible either telegraphing thru or visually through the material.
59. Smoothness of outside surface of base coat.
60. Skim coating of outside of base coat.
61. Installing diagonal (45)° 'butterfly' meshes at all corners of openings is required.
62. Application of extra base coat layers only after first layer is cured per manufacturer's recommendations.

Curing of Base Coat:

63. Weather and protection.
64. Adequate time per manufacturer's recommendations.

Inspection of Base Coat:

65. Smoothness
66. Repair of damage (if any). Mesh must not be visible, neither color nor shape.

Preparing Finish Coat:

67. Proper color and type.
68. Mixing tools and technique.

Applying Finish Coat:

69. Adequate tools and manpower.
70. Weather and temperature conditions.
71. Matching to approved color/texture samples.
72. Tool and technique for getting finish onto wall.
73. Tool and technique for texturing the finish.
74. Details at terminations regarding sealant bonding. Sealants can only be installed on base coat, not on topcoat.

Drying of Finish Coat:

75. Temperature
76. Weather (rain, wind, relative humidity).
77. Temporary weather protection until building is closed-in. Protection from damage by other subcontractors.

Panels, General:

78. Coordination with other trades (built-in windows, and so on).
79. Tolerances of the building structural frame.

80. Floor space requirements for fabrication.
81. Availability of hoisting/ overhead crane for fabrication

Panels, Engineering:

82. PE stamped calculations, submittal, and approval/ shop drawings
83. Design of structural connections, including tolerances accommodation/ installation adjustability by PE.

Panels, Shop Drawings:

84. Ordering of materials (studs cut-to-length).
85. Dimensions taken from existing building instead of from drawings, actual field dimensions are required.
86. Submittal and approval of shop drawings.
87. Panel identification.
88. Erection sequence / plan
89. Panel-to-building connections- tolerances.
90. Panel lifting points and CG calculations.
91. Design of special rigging/ lifting fixtures.

Panels, Fabrication:

92. Use of welding fixtures.
93. MIG welding process.
94. Touching up of welds.
95. Use of bridging.
96. Checking dimensions.
97. Minimizing of movement of panels.
98. Access to panel surface for application of finish.
99. Curing of adhesives and finish.

Panels, Storage and Lifting:

100. Protection from weather and temperature.
101. Lifting process and special lifting fixtures.
102. Storage of panels at panel plant and on-site.

Panels, Transportation:

103. Stacking method - storage, transportation
104. Protection from weather, transportation to job site, tie-downs, delivery schedule

105. Off-loading sequence.

Panels, Erection:

106. Crane (type, crane "reach", capacity, availability, rigging), site access and layout.

107. Crew on grade and on building.

108. Alignment instruments, survey, story poles.

109. Protection until the building is closed-in.

110 Erection sequence/ schedule

Sealants

111. Verify all penetrations have been sealed.

111. Sealants can be flush or recessed.

112. Verify that type of sealant is what EIFS Manufacturer System approved.

113. How does sealant manufacturer evaluate, support and police its installers?

114. Does the EIFS manufacturer publish its own protocols for installing of sealant? Have you included them in your documentation?

115. Will the sealant manufacturer perform field tests (pull test) for elongation and adhesion for all substrates and interfacing materials?

116. Use certified skilled mechanics for installation of sealant system.

117. Follow sealant manufacturer’s installation instructions.

118. Use fresh sealant materials that have arrived at the job site in their original unopened containers and are stored properly

119. Inspect joint for proper design in accordance with contract documents, manufacturer’s recommendations, regarding: width, depth, location, substrate, and primers. Report discrepancies to architect and correct prior to installation of sealant system.

120. Make sure all joints are clean and free of foreign matter: moisture, dust, front, sealers, release agents and EIFS finish coat. <u>Sealants are installed on base coat only.</u>

121. Install sealant system only when climate conditions (temperature, humidity) are acceptable and meet sealant manufacturer’s recommendations.

122. Protect adjacent materials from damage during installation. Be careful when using ladders, man lifts, and swing stages to install sealant to an EIFS system.

123. Allow all EIF products to cure fully prior to sealant application.

124. Apply coat of color coordinated EIFS recommended coating, or primer to wall of joint where only basecoat has been installed. DO NOT PUT FINISH COAT IN BOND LINE FOR SEALANT.

125. Install sealant primer, closed cell backer rod, or bond breaker tapes.

126. Remove any sealant primer over spill.

127. Mix sealant completely and according to instructions.

128. Use proper equipment, nozzles.
129. Tool the sealant properly. Soap tooling is not permitted.
130. Protect sealant from damage during curing.

Plan and Specification Review Prior to Bid/ Post Bid

1. Subcontractor site-specific safety plan to be submitted for approval – including hoisting, MSDS, aerial access operation by qualified personnel, stages, scaffolding, design by professional engineer (P.E.).
2. Dew Point Analysis conducted by A/E to determine if or where the dew point occurs in the wall system.
3. Require that the both the plans and contract specifications are in concert with the EIFS manufacturer specifications and with the detailed drawings for the wall system to be constructed.
4. Require that the shop drawings submitted be in accordance with EIFS manufacturer specifications and detailed system drawings.
5. Require that the shop drawings be detailed so that water penetration shall be prevented and so that damage will not occur to the composite wall assembly.
6. Proper substrate as recommended by EIFS manufacturer.
7. Proper flashing, trim, and accessories are specified and detailed in accordance with architect and EIFS manufacturer.
8. Minimum thickness is ¾" foam, maximum 4" foam.
9. Expansion joints properly located in accordance to EIFS manufacturer specifications and details. Shop drawings to include isometrics of the expansion joints, penetrations, terminations, flashings, end dams, fenestration openings – windows, doors, louvers, penetrations
10. Minimum width of expansion joint is specified and detailed in accordance with EIFS manufacturer and sealant manufacturer to allow for bond breaker/backer rod and the appropriate sealant contour.
11. Proper shop drawing detailing to prevent water penetration at dissimilar materials.
12. Proper shop drawing detailing of windows, including head and sill flashings, to prevent water penetration.
13. Drip details specified as required by EIFS manufacturer and contract documents.
14. EIFS should not be used as a parapet cap or windowsill.
15. Parapet is detailed to prevent water penetration and in accordance with EIFS manufacturer for flashing.
16. Proper transition from EIFS to roof base flashing to prevent water penetration in accordance with EIFS manufacturer.
17. Proper termination at concrete.
18. Proper termination above grade.
19. Proper detailing at foundation.

20. Contractor and supervision certification for system installation required.
21. Warranty called out.

Sheathing Substrate

1. Sheathing type.
2. Proper sheathing in accordance with project specifications, EIFS manufacturer and drawings.
3. Proper thickness.
4. Proper fastener type.
5. Proper fastener installation and spacing, including that the fasteners are installed per manufacturers recommendations for weather resistance
6. Butted tight and/or sealed per the sheathing manufacturer’s recommendations.
7. Clean
8. Dry
9. Level/Plane.
10. Temporary protection provided when necessary.
11. Undamaged

Masonry Substrate

1. Porous
2. Free of efflorescence.
3. Unpainted
4. Free of release agents.
5. Clean surface.
6. Dry/Free of frost.
7. Plane to ¼" in 10’-0".
8. Undamaged

EIFS Material Inspection

9. Properly stored on jobsite.
10. Correct adhesive and manufacturer per contract.
11. Adhesive batch number recorded.
12. EPS in proper bags as delivered.
13. Insulation board certification attached.
14. Correct base coat material.
15. Base material batch number recorded.

16. Correct mesh, with type used recorded.
17. Correct finish coat material.
18. Finish batch number recorded.
19. Finish lot number recorded.

EPS/Adhesive Inspection

20. Substrate as specified. Manufacturer's technical representative or third party certified EIFS inspector should inspect completed substrate prior to EPS installation.
21. Proper mixing of adhesive. Premixed materials are preferred.
22. Proper adhesive pattern for specified substrate and type of adhesive.
23. Proper adhesive thickness for type used.
24. Full contact with substrate.
25. Proper temperature maintained during application and curing.
26. Insulation board minimum thickness of ¾".
27. Insulation boards butted tightly with no gaps.
28. Insulation boards installed flat and in correct pattern.
29. Gaps between insulation boards filled with slivers of insulation board. Adhesive and base coat not permitted to fill gaps.
30. Insulation joints staggered from sheathing joints.
31. Corners interlocked per detail.
32. Insulation board installed in running bond pattern.
33. Insulation board clean, dry, entire wall surface rasped flat and all rasping dust removed prior to base coat.
34. Minimum thickness of EPS board ¾" maintained at bottom of aesthetic joints.
35. Yellowing of insulation board from extended exposure removed by adequate rasping.
36. All expansion and aesthetic joints installed.
37. EPS back wrapped at all terminations.
38. EPS back wrapped at all penetrations.
39. Proper space provided for the required width of sealant joints- review installation/ dimensions/ tolerances of adjacent materials.
40. Drip grooves where required.
41. Damaged insulation boards replaced.

Mesh/Base Coat Inspection

42. Proper mixing of base coat. Manufacturer's technical representative or third party certified EIFS inspector should inspect completed EPS prior to base coat application. Premixed materials are preferred.

43. High-impact mesh applied where required per contract documents.
44. High-impact mesh installed as first layer and butted tightly.
45. Diagonally reinforced with mesh at all window/door openings (butterfly).
46. Base coat mixture applied prior to embedding mesh.
47. Mesh lapped minimum 2 ½".
48. Reinforcing mesh fully embedded at all corners.
49. Mesh lapped minimum 8" at outside corners.
50. Reinforcing mesh fully embedded in aesthetic joints.
51. Base coat mixture applied to proper thickness.
52. Reinforcing mesh fully embedded with no mesh pattern showing.
53. Base coat mixture applied smoothly and free from trowel marks, etc.
54. All exposed edges of insulation board covered with reinforced mesh and base coat at all penetrations through system.
55. Proper temperature maintained during application and curing.

Finish Inspection

1. Lot numbers checked and recorded.
2. Reinforced base coat properly cured.
3. Reinforced base coat free of all irregularities.
4. Reinforced base coat clean, dry, and free from dust, dirt, efflorescence and other foreign materials.
5. Proper amount of clean potable water added consistently to all containers for mixing base coat.
6. Finish applied to proper thickness and per mock up.
7. Texture per approved sample and per mock up.
8. Sufficient manpower to finish distinct wall areas in deference to temperature conditions at the site
9. Wet edge maintained and cold joint prevented by proper planning.
10. Finish applied to all edges.
11. Finish is not applied where an expansion joint/sealant joint is installed.
12. Scaffolding installed at proper clear distance to permit EIFS installation to prevent scaffold damage to the EPS and finished EIFS.
13. Temperature monitored during installation and procedures implemented during application and curing to prevent cold joints, fully embed mesh, install laps, butterflies and other details.
14. Finish properly protected against rain after installation.
15. Flashing installed prior to completion of system application.

16. Sealant installed after wall system installed and cured to prevent water infiltration.

M.1-3 Commercial Low Slope Roofing Systems Checklist, 07500

(Construction & Industry Checklist for Commercial Low Slope Roofing Systems, 07500, Division 7, Thermal and Moisture.)

1. Verify the roofing subcontractor is installing the specified products and is installing the specified products in accordance with the manufacturer's written instructions.
2. Verify the roofing subcontractor is authorized by the manufacturer to install the products.
3. Verify the roofing materials are being stored in accordance with the manufacturer's recommendations.
4. Verify the roofing subcontractor is protecting its employees from fall hazards in accordance with applicable OSHA regulations.
5. Before roofing contractor is allowed to commence work verify that:
   (a) Surfaces are free from foreign material.
   (b) Excess mortar or concrete is removed; all holes, joints and cracks are pointed, and rough or high spots are ground smooth.
   (c) Wood-nailers or other attachment conditions are adequate.
   (d) Surfaces are dry to receive membrane heated asphalt, coal tar, and petroleum solvent asphalt mastics. Surfaces are tested for dampness if necessary.
   (e) All materials to be used must be dry and dew free.
   (f) Slope is as required. If roof surface does not have sufficient slope, contact architect.
   (g) Pipes, conduits and other items penetrating the membrane are in place and ready to receive flashings.
   (h) Open penetrations to have OSHA approved cover.
   (i) All sheet metal and roof accessories are in place or on hand to be installed in conjunction with roofing as required.
6. Verify materials of types required are provided. Verify softening point of bitumen is as required. Verify materials are identifiable and comply with ASTM or FM standards. Verify roll roofing is stood on end and kept free of contact with earth or moisture. Verify protective coverings of stored roll roofing are vented so condensation will not occur.
7. Verify nails and fasteners are of length, shank, head, and coating as required.
8. Verify felts for use with asphalt are asphalt-saturated; felts for use with coal tar pitch are coal tar saturated.
9. Verify surface to receive roofing is primed or otherwise prepared if required.
10. Verify asphalt or pitch is not overheated. Check kettle thermometer. Verify methods to transport heated material are provided to avoid overcooling. Measure installation temperature, periodically. If asphalt is being used, heated requirement is EVT, plus or minus 25°F, at point of application (EVT – Equiviscous Temperature – is the temperature, at which asphalt will attain a viscosity of 125 centistokes which is the practical and optimum temperature for wetting and fusion at the point of application). This can be done visually

or with an infrared thermometer. In the event EVT information is not furnished by the manufacturer, the following maximum heating temperatures should be used as guidelines:

(j) Dead Level Asphalt Type I 475°F maximum

(k) Flat Grade Asphalt Type II 500°F maximum

(l) Steep Grade Asphalt Type III 525°F maximum

(m) Special Steep Asphalt Type IV 525°F maximum

11. In no case should kettle or tanker be heated above flash point, if this occurs bitumen should be removed and not used. Final blowing temperature should not be exceeded for more than four hours.
12. Roofing materials should not be applied unless correct bitumen application temperatures can be maintained. Ensure that the correct temperatures are maintained. Applications of BUR below 40 degrees require special guidelines; request these from the roofing materials manufacturer.
13. Observe lap, mailing, and quantity of pitch or asphalt applied. In no case should felt touch felt; and there should be no bare spots.
14. See that felts are laid so that each layer is free of air pockets, wrinkles, and buckles. Brooming may be required. Glass fiber felts should not be broomed. Do not allow "flopping" of roofing felts, except in the application of cap sheets. See that no felt touches felt. Verify mopping is full to ply lines.
15. Phased application of a traditional BUR roof should be avoided. A four ply roof should have all four plies laid at once, not two and two. If a single or double ply is installed in an emergency to protect the insulation in a storm, it should be allowed to dry, and four plies applied over these.
16. Verify all surfaces are kept moisture-free. Under no condition allow exposure of insulation or felts over night without a mopping. Verify stored material from moisture.
17. When felt layer equipment is used, observe that jets are clear and an adequate and uniform layer of bitumen is deposited.
18. Observe installation of roofing at cant strips, vertical surfaces, reglets, and penetration. Observe sealing of roofing membrane envelopes where use of envelope is required.
19. Verify concrete walls to receive roofing are primed. Verify wall membranes are properly prepared and attached or fastened as specified.
20. Observe aggregates for surfacing of type, color and size, specified, clean, and dry.
21. Verify aggregates in quantity required are spread over flood coat while bitumen is hot.
22. Verify roll roofing or cap sheet, if utilized, is of weight, selvage, finish, and color, as required. Verify cap sheet installed as required.
23. Verify operations are performed in a manner to avoid plugging of drains, and weeps and do not damage or interfere with adjoining surfaces.
24. Observe that roof drains are set to permit proper drainage.
25. Verify roofing plies are mopped into clamping ring. Verify lead collar flashing is installed and stripped in, if required.

26. Verify roofing is protected from damage by other trades or by general contractor during installation and following completion. If subject to heavy traffic, movement of equipment, storage or materials, or used as a work surface, verify that runways, plywood sheets or other protection is provided.
27. Limit traffic on newly installed plies to minimize bitumen displacement. This can lead to blisters and leaks. This <u>includes</u> roofers until cooled.
28. While torching Atactic Polypropylene Modified bitumen (APP), do not torch directly to a flammable substrate (wood nailers, wood fiber cant, or flammable insulation).
29. When using a torch on an existing building, be aware the negative pressure can suck the flame through a crack and start a fire inside a wall or curb.
30. Observe and/or cut samples if required. Verify patching is properly performed where samples are cut. Samples are to be taken before finish surface (aggregate, cap sheet, emulsion) is applied.
31. Verify clean up is provided after installation, drains cleared and debris is removed from site.
32. Require submittal of shop drawings, MSDS sheets, technical data, site specific safety plan

Single Ply

1. Use sleepers and slip-sheets under all equipment.
2. Limit smoking, cutting, or hot work on roof, to avoid damage, and fires from flammable glues. Require hot work permits.
3. EPDM <u>no moisture</u> in seams of roof. "A clean seam is a good seam."
4. EPDM cold weather application is common, but not below or at freezing, due to newer glue formulations. Verify product specified is appropriate to site conditions.
5. Verify substrate temperature with an infrared thermometer at the start of each work shift.

M.1-4 Flashing and Sheet Metal Checklist, 07600

(Construction & Industry Checklist for Flashing and Sheet Metal, 07600, *Division 7, Thermal and Moisture Protection)*

1. Verify delivered material is of approved type, shape, gauge, metal, fabrication, and priming, as required, and all accessories are provided.
2. Verify isolation provisions are made for dissimilar metals. Do not allow copper and aluminum flashings to be in contact with each other or with ferrous metal. Copper or aluminum flashings are to be fastened with non-ferrous nails or screws. Ferrous equipment bases are not to be set on copper flashings. Verify that flanges embedded in plastic cement or asphalt are asphalt primed.
3. Verify expansion joints are provided and installed as required or as specified. Note location of joints with respect to drains, downspouts, scuppers, corners, and other outlets.
4. Observe methods of installation – nailing and cleating types for spacing and location; also soldering, welding, bolting, and riveting.
5. Verify flashing does not interfere with structural requirements.
6. Generally see that edge metal is lapped a minimum of 4 inches with 12 inches staggered nailing or fastening through the back flange unless otherwise required.
7. Verify all edge metal laps are coated with sealant on horizontal flange and vertical rise. Verify that coating covers the entire lap and is sandwiched between.
8. Verify lengths are as long as practical or specified.
9. Verify installation is coordinated with roofing and/or siding installation.
10. Verify that a nailer or cant strip is provided for fastening flashing to roof deck is of proper material, well secured, and allows venting if required or specified.
11. Verify flashing is embedded and installed over roof membrane assembly with additional roofing membrane material.
12. Verify method of anchoring lower edge of fascia is as required. Observe alignment, and stiffness.
13. Verify gravel stops are flush with deck unless otherwise required.
14. Construct mock-ups and field water test.

Gutters

1. Verify gutters are adequately supported and allow for movement. Observe attachment size, type, location, and spacing of hangers and supports.
2. Verify gutters are pitched if required and provide for drainage to outlets.
3. Verify gutter joints are lapped in direction of flow.
4. Verify expansion joints, concealed or standing, are provided midway between outlets or downspouts and/or as required.

5. Verify scuppers are installed low enough not to retain dam water on roof. Verify overflow drains and scuppers if indicated or required by code are provided, located properly, i.e., low point of roof, are of size required and have correct inlet flow elevation.
6. Verify accessories are provided if required – basket strainer, bird screens, and covers.

Downspouts

1. Verify lengths are as long as practical and in accordance with specifications.
2. Verify slip joints in direction of flow or allowance for movement is provided.
3. Verify hangers or straps as required are provided. Verify spacing and location are as required or specified, and each section is supported. Connection of hangers does not damage finish wall material.
4. Verify contact is not made with wall surfaces except for supports.
5. Verify downspouts are installed plumb, without excessive lateral or angled joints, unless indicated or if required to conduct drainage.
6. Verify special items are furnished: heads, scuppers, and linings.
7. Verify downspouts that are indicated to terminate in drainage lines are nearly fitted and are cleaned and free of building debris or other materials.

Base and Cap Flashings

1. Verify flashing is provided to suit condition - cant, size, gauge, and fabrication.
2. Verify base flashing extends up sufficiently; flange is properly secured and embedded at least 4 inches in roofing membrane and is installed similarly to gravel stops. Verify mopped felt or suitable membrane covering flashings or cleats is provided. It is good practice to cover as much metal as practical to avoid movement from temperature variations.
3. Verify seams are lapped, locked, and soldered as required.
4. Verify secure anchorage is provided for size, spacing, and fixing of cleats or other equipment mountings.
5. Verify cap flashings are of shapes, sizes, and gauges required and are installed to provide secure anchorage, allow movement, and have sufficient laps and spacing.
6. Verify counter flashing is extended sufficiently into masonry walls or into reglets and is securely anchored and caulked, if necessary.
7. Field water test – flashings, laps, terminations, caps

Other Roof Flashing

1. Verify hip and ridge flashing and venting is provided as required. Check fabrication, size, gauge, anchorage, and lap. Observe caulking and painting procedures.
2. Verify valley flashing is provided as required: open or closed, width, gauge, anchorage, and lap.

3. Verify stepped flashing is provided as required: depth of insertion into wall, and length of material attached to deck and lap. Verify plastic cement or approved material is filled into joints between edges of shingles and flashings as required.
4. Verify reglets are provided at required areas: observe the setting in concrete or masonry to assure firm anchorage. Verify reglets are protected to prevent deformation or filling during installation.
5. Observe installation of sheet metal into reglets for tightness, weatherproof ness, caulking, and lap.

Wall and Through Wall Flashing

1. Verify locations for flashings fabrication and design with contractor.
2. Verify lap, turn up, location in wall, depth in masonry, length, are as required.
3. Verify sill flashing and pans extend full depth, are turned up, extend beyond horns or 4 inches, and are installed for proper drainage.

Miscellaneous

1. Verify louvers and vents have adequate flanges and connections for anchorage and flashings are watertight against driving rains after installation. Verify insect screen, bird screen, and shutters are provided as required.
2. Review drawings and specifications for sheet metal items.
3. Items such as skylight, roof, hatches, and fans may be suited for installation with or without flashing. Verify installation meets manufacturers' specifications when required.
4. Verify plastic flashing is of type required and is installed in accordance with requirements.
5. Verify sheet metal termite shields are provided as required.

M.1-5 Joint Sealers Checklist, 07900

(Construction & Industry Checklist for Joint Sealers, 07900, Division 7, Thermal and Moisture Protection)

1. Verify product specified is appropriate to site conditions.
2. Verify subcontractor is authorized by manufacturer to apply product.
3. Is product compatible with substrate?
4. Has surface been properly prepared?
5. Is primer being used when required?
6. Is the proper sealant installation technique being used including application, bond breakers, field-testing, storage, shelf life, etc.
7. Depth should never be larger than width of caulk joint.
8. General rule: acid cure sealants are generally compatible with clear glass, metals, plastics, and painted surfaces (primer may be needed). These types of sealants release ace-

tic acid during cure. Not compatible with concrete, limestone, marble, lead, zinc, or substrates attacked by acetic acid.

9. Open cell backer rod must be removed if rained on.
10. Verify exposed areas have been masked to protect adjacent work and product.

Surface factors and preparation for concrete:

1. Can have the most variable surface conditions.
2. Formulation of concrete, curing conditions, moisture, and form releases.
3. Improper formulations can cause weak surfaces.
4. Weak surfaces may need sandblasting, grinding, or wire brushing.
5. Contaminated surfaces must be completely removed.
6. Every day of rain means two days to dry.
7. Moisture in or on surface difficult to detect.
8. May look and feel dry to the touch, but moisture may be in the core.
9. Moisture can form to frost below 32° F; frost will affect adhesion.
10. Frost may be minimized with solvent wipe to surface.
11. Sealant must be applied immediately after solvent evaporates.

Stone

1. Typically good surfaces for sealant adhesion.
2. Should always be checked for compatibility.

Glass

1. Typically excellent surface for sealant adhesion.
2. Always test for compatibility on coatings or laminates.
3. Surface preparation required prior to sealant installation.

Metals, Mill Finish Aluminum

1. Contains mill contaminants such as oil, graphite or carbon.
2. Can be difficult to clean and oxides easily.
3. Not approved for structural glazing applications.
4. Primer required for dynamic joint conditions.

Metals

1. Anodized aluminum typically provides excellent adhesion; test before if possible.
2. Typically does not require a primer.

3. Oils and airborne contaminants easily deposited on new construction.
4. Lead, copper, stainless, and galvanized use neutral cure sealants.
5. Unpainted steel or unprimed steel will rust causing sealant failure.
6. Always test for sealant compatibility and adhesion.

EIFS

1. Sealant must be applied to base coat of EIFS to resist softening due to water saturation of the topcoat.
2. EIFS is a difficult substrate to adhere to.
3. Be aware of failures related to breakdown of acrylic emulsion-based finish coats.
4. Backer rods should be non-gassing closed cell foam.
5. Low modulus silicone minimizes bond line stress and delamination.
6. All EIFS must be primed.
7. Base coat must be allowed to dry prior to sealant installation.
8. Sealant surface must be sound and free of moisture.
9. Always monitor and verify adhesion throughout sealant application.

Proper Use of Primer

1. Be sure specified primer is being used. Primers are not all identical.
2. Never dip brush or rag in original primer container.
3. Primer should be poured into a clean small container.
4. Apply with a natural brush or clean lint free cloths.
5. Fully wet surface with primer, do not puddle on horizontal.
6. Allow primer time to dry until tack free (5-15 minutes).
7. Primers should never be applied to glass.
8. Do not prime more than can be sealed in one hour (field) two hours (shop).

Back-Up Materials

1. Install backer rod to the depth specified, make sure depth is uniform.
2. Ensure primer is dry prior to backer rod placement.
3. Do not twist rods, for this will create a poor sealant profile.
4. Use correct size specified; not doing so can affect adhesion performance.
5. Always center backer rod or bond breaker tape in center of joint.
6. Typically open cell polyurethane rods are acceptable (but not with EIFS).
7. Only use closed cell (non-gassing) type polyethylene rods.

Proper Sealant Installation

1. Apply sealant making sure sealant is filling joint slot.
2. Make good contact to the sides of the joint; avoid skips and air pockets.
3. Slowly fill the bead slightly ahead of the nozzle travel.
4. Tool the sealant into the joint and force against the joint for proper adhesion and contact to substrate.
5. Where possible concave face of sealant to "hour glass" profile.
6. <u>Do not</u> use soap or cleaning solutions to tool sealants.
7. Tool sealant before it starts to skin over.
8. Remove masking tape prior to sealant starting to skin over.
9. Do not disturb sealant once applied in joint.
10. <u>Do not</u> pull sealants.
11. Always use white lint free cloths for clean up.

Post Application Adhesion Tests and Storage of Sealant

1. Verify sealant adhesion to all substrates.
2. Most sealants have a 6-24 month shelf life if stored properly.
3. Never use out of shelf life sealant.

M.1-6 Entrances and Storefronts Checklist, 08400

(Construction & Industry Checklist for Entrances and Storefronts, 08400, *Division 8, Doors and Windows)*

1. Field measure prior to installation.
2. Cross-reference all related submittals, as well as specifications and plans.
3. Know where interior items intersect storefront glazing, and how it will be handled.
4. Copy all information to all subcontractors involved.
5. Be aware of surrounding materials and the connections to the doors and frames.
6. Follow all manufacturers instructions.
7. Secure approval for all mock-ups or irregular instances ahead of time by the Architect.
8. RFI any discrepancies immediately.
9. Provide dollars to cover the cost for the extra care and handling involved in this section.
10. Consider other trades when scheduling the installation.
11. Allow for proper protection of the glazing from other trades.
12. Verify components or pre-assembled panels are checked for shipping damage after un-crating; and size, shape, thickness of metal extrusions or parts match full size details

when available. Check that gauges, patterns, and colors are as approved and match samples.

13. Verify protective coating and/or lacquers are provided to proper thickness.
14. Verify shop-applied sealant is provided at shop-assembled joints as required.
15. Verify field-applied sealant is provided as required.
16. Verify color matches between panels and parts are within specified range.
17. Verify dissimilar metals and materials are isolated; for example, aluminum, in contact with other metals and cementitious surfaces, may require nylon, polystyrene or pressure tape, separators or stainless steel bolts.
18. Verify field-applied sealant is of proper type and color and applied where required. Verify sealant joint widths are correct.
19. Verify expansion joints are provided between units as required.
20. Verify weep holes and drainage systems are provided and are clean before and after erection.
21. Verify installation tolerances are maintained regarding horizontal and vertical alignment and plumbness.
22. Verify reveals are of consistent size and alignment.
23. Verify anchorage to structure is secure for transfer of wind load and is required and permanently tightened after alignment.
24. Verify hardware provisions have been coordinated.
25. Verify electric or pneumatic outlets and locations, if required, are provided.
26. Verify exterior is maintained reasonably clean after installation. Clear all cementitious materials from surfaces.
27. Verify final cleaning is performed as required.
28. Verify doors, openings and space at doors allow for accessibility requirements. (ADA)
29. Conduct water test (hose test) of the installed assembly.
30. Obtain manufacturer's touch-up painting procedures
31. Field water test thresholds, flashings, end dams.

M.1-7 Windows Checklist, 08500

(Construction & Industry Checklist for Windows, 08500, *Division 8, Doors and Windows)*

1. Verify delivered windows are of type, size, finish, and operation as approved.
2. Verify windows are properly stored and clipped shut until hardware is installed.
3. Verify hardware is of required type, metal, finish, and function.
4. Verify special items are furnished, such as window cleaner’s bolts, pull-down hooks, poles, special mullions, and trim.

5. Verify required type of glazing beads or stops are provided, and are suitable to receive glass and glazing thicknesses. Verify method of fastening is as required.
6. Verify windows are set plumb, square, and level in alignment and at proper location and elevation.
7. Verify windows have provision for suitable anchorage, and it is provided during installation. Verify windows are adequately braced where "built in".
8. Verify windows are sealed as required for metal-to-metal surfaces and other surfaces. Observe that solid grouting, caulking and backup are provided if required.
9. Verify finish is protected and maintained during and after installation. Observe that protection against cement, plaster, acids, and other harmful materials is provided.
10. Verify windows are installed to be weather tight. Observe that weeps are provided, if required, and are maintained in a clean condition.
11. Ensure dissimilar metals are isolated.
12. Verify windows are properly adjusted for tolerance, clearance, and operation before glazing.
13. Observe glazing operation. Verify type of sealant is as required and applied in accordance with instructions.
14. Verify cleaning of metals and glass is properly performed.
15. Verify that screens of proper type, mesh, and size are provided, if required and suit installation.
16. Test operable windows for hardware and friction adjustment and ease of operation on completion of installation.
17. Obtain detailed installation instructions from manufacturer.
18. Verify compatibility of sealants.
19. Obtain cleaning recommendations from manufacturer.
20. Perform field water test/ hose testing of flashings, end dams, sub sills, prior to window installation.
21. Obtain warranties.

M.1-8 Skylights Checklist, 08600

(Construction & Industry Checklist for Skylights, 08600*, Division 8, Doors and Windows)*

Skylights - General

1. Verify Manufacturers/ Installers qualifications.
2. Verify Manufacturers/ Installers warranty.
3. Verify schedule for installation / weather factors.
4. Prior to installation, verify support and adjacent construction is properly prepared to receive the work.

5. Verify all materials are free from defects and/or damage prior to installation.
6. Verify system is plumb and true in relation to established lines and approved shop drawings.
7. In a pressure plate system, verify horizontal pressure plates are embedded in silicone; not just caulked around.
8. Verify all fasteners are compatible with the skylight support/framing system.
9. Verify protection of completed work from abuse and foreign matter.
10. Ensure owner has received a copy of the warranty and cleaning/maintenance instructions.

Framework

1. Confirm anchorage of skylight to structure is in accordance with approved shop drawings.
2. Verify retainer bars are attached with gasketed stainless steel fasteners spaced at a maximum of 9" on center.
3. Verify maximum variation from plane or location shown on approved shop drawings in 1/8" per 12’-0" or ½" in the total length.
4. Ensure deflection of any framing member shall not exceed ¾" within any glass panel.

Glass

1. Verify glass lites comply with the specifications.
2. Check glass labels for proper setting of lite and glass type.
3. If glass used is heat strengthened or tempered on the interior side, verify a screen has been installed within 100 mm. or 4" of the glass.
4. Ensure glass is resting evenly on setting blocks to avoid shear action.

Flashing

1. Sheet metal flashing should be shop formed in a minimum of 10’-0" or 3.04 m lengths.
2. Verify sheet metal flashing ends overlap a minimum of 6" – 8" and set in full bed of sealant.
3. Ensure flashing details should meet the standards of the National Roofing Contractors Association and/or SMACNA.
4. Field water test – flashings and end dams prior to installation of the skylight

Glazing Strips

1. Verify no visual cracks or breaks in glazing strips.
2. Interior glazing gaskets must maintain a 3/16" minimum separation between glass and frame.
3. Interior glazing gaskets must maintain a ½" minimum bite of glass.

Sealants

1. When backer rod is used, verify uniformity in the depth of the joint.
2. Verify all dirt, dust, moisture, and other foreign matter is removed from surfaces to receive sealant.
3. High performance silicone sealant is utilized at structural joints.
4. Verify allowable ambient temperatures for installation of sealants with an infrared thermometer.
5. Verify that the sealant is compatible and functional with the substrates.

Skylights with Integral Drainage Systems

1. If integral gutter system is utilized, verify positive drainage.
2. Verify weep/gutter is clear of caulking and/or debris.

Testing

1. Verify no water penetration when tested in accordance with the specifications. Water penetration is defined as the appearance of uncontrolled water other than condensation on the interior surface of any part of the skylight.
2. Air infiltration shall be limited to the specified allowance. ASTM E283-84 allows an infiltration rate of 0.23 cfm/m or 0.50 cfm/ft. under 11kPa or 1.57 psi of pressure.
3. Ensure adhesion tests have been submitted to verify adequate adhesion of sealant to samples of metal and glass to be used on the project.
4. Obtain aluminum extrusion test reports that verify the material meets industry standards for strength and chemical composition.

M.1-9 Glazing Checklist, 08800

(Construction & Industry Checklist for Glazing, 08800*, Division 8, Doors and Windows)*

Glazing - General

1. Verify types, thickness, quality, pattern, and finish of glass are as required and glass is labeled or otherwise identified.
2. Verify type, materials, and methods of glazing. Verify putty, glazing compound, tape, gasketing, glazier points, screws, shims, separators, beads, and special sections are as required.
3. Verify surfaces to receive glass are dry, clean, and properly prepared.
4. Verify wood and steel rabbets and beads are primed before glazing; lacquer and grease are removed from metals; and weathering steel is primed or otherwise prepared.
5. Verify required clearance between glass and frames is provided (extremely important for plastic panes).

6. Verify heat-absorbent glass has clean-cut edges. If altered at site, see that this condition is met.
7. Verify no alteration or attempt to alter size or edge of heat-strengthened, tempered, or insulating glass is made on job.
8. Verify glazing blocks and shims are provided for proper positioning and setting as required.
9. Verify embedding requirements, such as puttying and back puttying, use of points, and use of putty or compound are as required. Observe that corrosion-resistant fasteners are used. Verify glazing compound or sealant is applied in accordance with manufacturer's requirement, including proper rod stock material.
10. Verify plastic panes are protected with covering. Verify covering is removed after installation where exposed to sunlight. Verify plastic panes are protected from paint, tar, plaster, and solvents, and cleaning is performed in strict accordance with manufacturer's recommendations. Look or bubbles or scratches.
11. Verify patterned glass is set in exterior opening with smooth side to exterior. Verify pattern of adjacent panes is consistent.
12. Verify gasketing in metal sash is not painted.
13. Verify stop beads are securely fastened and non-removable types are used if required.
14. Verify interior glass is installed using required soundproofing methods and is otherwise vibration free.
15. Verify mirrors are installed using soundproofing methods required and is otherwise vibration free.
16. Verify requirements are met for maintaining labels and protective identification on glass until final cleaning.
17. Verify cleaning of glass is performed properly per the manufacturer's recommendations without scratches, and all surfaces are free of labels, putty, compounds, and paint.

M.1-10 Glazed Curtain Walls Checklist, 08900

(Construction & Industry Checklist for Glazed Curtain Walls, 08900*, Division 8, Doors and Windows)*

General

1. Verify components or pre-assembled panels are checked for shipping damage after uncrating. Verify size, shape, and thickness of metal extrusions or parts match full size details when available. Check that gauges, patterns, and colors are as approved and match samples.
2. Verify protective coating and/or lacquers are provided to proper thickness.
3. Verify joint sealer is provided at shop-assembled joints as required.
4. Verify shop-applied sealant is provided as and where required, including per the Laboratory tested mock up.
5. Verify sound deadening material and/or insulation is provided as required.

6. Verify color matches between panels and parts are within specified range.
7. Ensure dissimilar metals and materials are isolated; for example, aluminum, in contact with other metals and cementitious surfaces, may require nylon, polystyrene, or pressure tape, separators or stainless steel bolts.
8. Verify field-applied sealant is of proper type and color and applied where required.
9. Verify expansion joints are provided between units as required.
10. Verify weep holes and drainage systems are provided and are clean before and after erection.
11. Verify erection tolerances are maintained regarding horizontal and vertical alignment and plumbness.
12. Verify reveals and align are of consistent size.
13. Verify anchorage to structure is secure for transfer of wind load and is required and permanently tightened after alignment.
14. Verify debris, such as spray fireproofing, is removed from within curtain wall sections after erection.
15. Verify exterior is maintained reasonably clean after installation, especially free from cementitious materials.
16. Verify final cleaning is performed as required.
17. Obtain manufacturer's installation instructions.
18. Obtain manufacturer's cleaning instructions and touch up painting instructions.
19. Obtain warranty.
20. Perform field water testing (of the flashings, end dams, sub sills prior to installation) per the project specifications.

Construction Checklist

BUILDING ENVELOP SYSTEM

Components included: ___ unit masonry, ___ limestone veneer, ___ cast stone, ___ sheet metal flashing & trim, ___ roof, ___ joint sealants, ___ wood windows/doors

1. Submittal / Approvals

Submittal: The above components and systems integral to them are complete and ready for testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ___ List attached.

Sealant Contractor	Date	Glazing Contractor	Date
Ext. Limestone Veneer Contractor	Date	Sheet Metal Contractor	Date
Masonry/Cast Stone Contractor	Date	Steel Fabricator	Date
General Contractor	Date	Roof Contractor	Date

Construction checklist items are to be completed as part of installation & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and installation procedures or reporting requirements.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- Contractors' assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CxA = commissioning agent, GC = general contractor, LVC = limestone veneer/sheet metal contractor, SC = sealant contractor, GLC = glazing contractor, UMC = masonry/cast stone/sheet metal contractor, RC = roof contractor, SMC = sheet metal contractor

Approvals: This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Owner's Representative	Date

2. Requested documentation submitted (filled out by CxA)

Building Envelope Component-> Check	Masonry	Limestone Veneer/ Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Manufacturer's cut sheets								
Installation details								
Manufacturer's requirements								
Shop drawings showing attachment and details grills & louver								
Architect of record has reviewed installation to see that placement is consistent with original design.								
Building envelop structural engineer of record has reviewed concentric connections between limestone and embeds and issued a letter of acceptance.								

- ***Documentation complete per contract documents for given trade............ ___ YES ___ NO***

3. Installation Checks (filled out by contractor)

Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______
Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______
Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______
Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
General Installation								
Building envelope component completed and cleaned per contract documents								GC
Dampproofing								
CMU are dry, free of dirt and excess mortar, sand and other construction debris before application of primer								UMC
Outside temperature is above 40 F during application of dampproofing								UMC
Dampproofing is 6-10 mils and pin hole free								UMC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Rigid Insulation								
CMU is plumb, level, true to line, and is free of obstructions that would inhibit good adhesion of insulation in dampproofing cement								UMC
Dampproofing is cured and ready for Insulation installation								UMC
Rigid insulation is securely bonded to CMU prior to exterior finish installation								UMC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								UMC
Roof								
Substrates and conditions under which ice & water shield are to be installed are dry, free of debris and satisfactory								RC
Ice & water shield lapped over flashing per contract documents								RC
Modified bitumen membrane laps per contract documents								RC
Cant strip installed at horizontal/vertical intersections per contract documents								RC
Metal flashing surfaces are dry, clean, free of grease, oil, dirt, and corrosion, and without sharp edges or offsets at joints.								RC
Lap joints are sealed in accordance with contract documents								RC
Flashing is installed in accordance with contract documents								RC
Limestone veneer								
Limestone is not discolored by contaminates								LVC
Anchors, dowels, fastenings, and hoisting fittings are properly installed Units are in good condition: not warped, distorted cracked, stained or otherwise damaged								LVC
Rigid insulation is securely bonded to CMU								LVC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								LVC
Flashing is installed in accordance with contract documents								LVC
Grouted joints are 3/8" ± 1/16" or less in width								LVC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Limestone is within specified tolerances ½" total height								LVC
Limestone corners are within specified tolerances 3/8" total height								LVC
Limestone within ¼" of plumb in 10 ft								LVC
Limestone is within ¼" of level in 20 ft, ½" in total run								LVC
Limestone is within ¼" of position or cross sectional dimension								LVC
Corner alignment of adjacent panels are within ± 1/32"								LVC
Steel anchors and attachments are in good condition								LVC
Limestone attachments are in line with structure attachment								LVC
Sufficient clearance between non grouted components to allow for proper backing rod and sealant installation								LVC
Cavity weep tubes are installed at sills, relieving angles, door and window heads, and embed joints								LVC
Horizontal weeps are at 5' centers or less, vertical cavity weeps at 20' or less								LVC
Weep holes are open and free of debris								LVC
Cast Stone								
Cast Stone is not discolored by contaminates								UMC
Anchors, dowels, fastenings, and hoisting fittings are properly installed. Units are in good condition: not warped, distorted, cracked, stained or otherwise damaged								UMC
Rigid insulation is securely bonded to CMU prior to placement of stone								UMC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								UMC
Flashing is installed in accordance with contract documents								UMC
Horizontal substrate is clean and free of debris prior to placement of drainage mat & waterproofing								UMC
Drainage mat and water proofing are installed according to contract documents								UMC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Vertical joints are ¼" unless otherwise indicated in contract documents								UMC
Cast Stone is within specified tolerances ±1/8" total height or width or length up to 2 ft								UMC
Cast Stone is within specified tolerances +1/16", -1/8" total length 2 ft to 5 ft								UMC
Cast Stone is within specified tolerances +1/8", -3/16" total length 5 ft to 10 ft								UMC
Cast Stone is within specified edge out of line tolerance of ±1/8"per 10 ft, ¼" maximum								UMC
Cast Stone corners are within specified tolerances 3/8" total height								UMC
Opening size ±1/2"								UMC
Opening location ±1/2"								UMC
Steel anchors and attachments are in good condition								UMC
Cast Stone attachments are in line with structure attachment								UMC
Ends of lugged sills and similar units are embed in mortar								UMC
Joints are raked to ¾" from face for pointing								UMC
Sufficient clearance between non grouted components to allow for proper backing rod and sealant installation								UMC
Excess mortar has been sponged off face								UMC
Rake joints have been allowed to set before application of pointing mortar								UMC
Cavity weep tubes are installed per contract documents								UMC
Weep holes are open and free of debris								UMC
Sheet metal flashing and trim								
Substrates and conditions under which sheet metal flashing and trim are to be installed are satisfactory								UMC LVC
Sheet metal complies with at least minimum specified thickness, weight, and grade.								UMC LVC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Exposed sheet metal is without excessive oil canning, buckling, and tool marks and is true to line and levels indicated, with exposed edges folded back to form hems.								UMC LVC
Surfaces were cleaned with no oils or foreign matter prior to sealing or joining together								UMC LVC
Lap joints are sealed in accordance with contract documents.								UMC LVC
Flashing between CMU & exterior finish is embedded in dampproofing and securely fastened								UMC LVC
Joints have been filled with sealant and metal formed to conceal sealant.								UMC LVC
Nonmoving seams in sheet metal and aluminum are fabricated with flat-lock seams								UMC LVC
Brick								
Brick color and texture matches mock-up								UMC
Anchors are properly installed								UMC
Rigid insulation is securely bonded to CMU								UMC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								UMC
Flashing is installed in accordance with contract documents								UMC
Mortar color matches mock-up								UMC
Anchors and attachments are in good condition and correctly spaced								UMC
Brick is within ¼" of plumb in 10' and within 3/8" per floor, and within ½" from base to roof line								UMC
Control joints are 25' or less apart								UMC
Sufficient clearance between non grouted components to allow for proper backing rod and sealant installation								UMC
Cavity weep tubes are installed at sills, relieving angles, door and window heads, and imbed joints								UMC
Horizontal weeps are at 2' centers or less, vertical cavity weeps at 20' or less								UMC
Weep holes are open and free of debris								UMC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Joint sealants								
Joints are sufficiently spaced to allow proper application of backing and sealant								SC
Backing material has been installed in accordance with sealant manufacturer's requirements.								SC
Materials delivered in original containers or bundles with labels showing manufacturer, product name or designation, color, shelf life, and installation instructions.								SC
Joints are completely filled.								SC
Full contact is made with bond surfaces and there is a minimum 3/8" width adhesion area.								SC
Surfaces are clean and dry prior to application of sealant								SC
Non-sag sealants have been tooled to smooth surface								SC
Surfaces adjacent to joints are clean								SC
Sealant has cured according to manufacturer's recommendations and is ready for testing.								SC
Grills & Louvers								
Rough or masonry opening is correct and sill plate is level.								SMC
Grills/louvers are plumb, level, and true to line								SMC
Sill members and other members have been set in a bed of sealant or with joint fillers or gaskets to provide weather tight construction.								SMC
Final								
Report completed with this checklist attached								GC
Finished surfaces are clean and not discolored.								GC
Exterior wall has been cleaned in accordance with contract documents within 48 hours of substantial completion date								GC

- ***The checklist items of Part 3 are all successfully completed for given trade.___ YES ___ NO***

4. Operational Checks (These augment mfr's list. This is not functional performance testing.)

Check Building Envelope Components->	Masonry	Limestone Veneer	Sheet metal	Sealants	Windows	Glazing	**Contr.**
All seals and joints are tight.							GC
System is waterproof as specified.							GC
Brick, limestone, cast stone are clean.							GC
Cavity drains remove moisture effectively preventing water build-up in the cavity.							GC

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

END OF CHECKLIST

Annex M.2:
Example Construction Checklist for Building Envelope System

Commentary: This sub-annex provides an example of a construction checklist for the building envelope (exterior enclosure) system.

Credits: The example checklist contained on the following pages has been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

Annex M.2:
Example Construction Checklist for Building Envelope System

Commentary: This sub-annex provides an example of a construction checklist for the building envelope (exterior enclosure) system.

Credits: The example checklist contained on the following pages has been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

Construction Checklist

WINDOWS & DOORS

Components included: ___unit masonry, ___sheet metal flashing & trim, ___joint sealants, ___wood windows/doors, ___glazing, ___limestone veneer, ___brick/cast stone

1. Submittal / Approvals

Submittal: The above components and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ___ List attached.

Masonry Contractor	Date	Glazing Contractor	Date
Interior Contractor	Date	Limestone Contractor	Date
Security Contractor	Date	Sealant Contractor	Date
General Contractor	Date		

Construction checklist items are to be completed as part of installation & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and installation procedures or reporting requirements.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- Contractors' assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, GC = general contractor, LVC = limestone veneer/sheet metal contractor, UMC = masonry /sheet metal contractor, SC = sealant contractor, GLC = glazing contractor, contractor CxA = commissioning agent, SCC = Security contractor

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Owner's Representative	Date

2. Requested documentation submitted (filled out by CxA)

Windows & Doors Component-> Check	Hardware	Sheet metal	Sealants	Windows & Doors	Framing	Jam & Threshold	**Contr.**
Manufacturer's cut sheets				Y			GC
Installation details		Y	Y	Y	Y		GC
AAMA 101 -97 test report by an independent laboratory for each window model and door configuration				Y			GC
ASTM E 330 test report by an independent laboratory for each window model				Y			GC
Shop drawings showing attachment and details							GC

- ***Documentation complete as per contract documents for given trade........ ___ YES ___ NO***

3. Installation Checks (filled out by contractor)

Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______
Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______
Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______
Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______

Check Windows & Doors Components ->	Hardware	Sheet metal	Sealants	Glazing	Framing	Jams & Thresholds	**Contr.**
General Installation							
Exterior windows & door components completed and cleaned per contract documents							GC
Sheet metal flashing							
Substrates and conditions under which sheet metal flashing and trim are to be installed are satisfactory							UMC LVC GLC
Sheet metal complies with at least minimum specified thickness, weight, and grade.							UMC LVC GLC
Lap joints are sealed in accordance with contract documents.							UMC LVC GLC
Surfaces were cleaned with no oils or foreign matter prior to sealing or joining together							UMC LVC GLC
Joints have been filled with sealant per contract documents.							UMC LVC GLC
Windows							
Color, quality and finish are with acceptable color range							GLC

Check Windows & Doors Components ->	Hardware	Sheet metal	Sealants	Glazing	Framing	Jams & Thresholds	**Contr.**
Window units are plumb, level, and true to line, without warp or rack of frames or sash. Proper support is provided and units are anchored securely in place.							GLC
Masonry surfaces are dry and free of excess mortar, sand and other construction debris.							GLC
Rough or masonry opening is correct with required clearance for proper installation of window							GLC
Metal surfaces are dry, clean, free of grease, oil, dirt, and corrosion, and without sharp edges or offsets at joints.							GLC
Sill members and other members have been set in a bed of sealant or with joint fillers or gaskets to provide weather tight construction.							GLC SC
Weeps are installed per construction documents							GLC SC
Weep holes are open and free of debris or blockages							UMC LVC GLC
Opening mechanism is installed							GLC
Security contacts are installed and function correctly							SCC
Joint sealants							
Windows are placed so that backer rod and sealant have sufficient bearing surface for proper adhesion and sealant reinforcement.							SC
Backing material has been installed in accordance with sealant manufacturer's requirements.							SC
Materials delivered in original containers or bundles with labels showing manufacturer, product name or designation, color, shelf life, and installation instructions.							GC SC
Surfaces are clean and dry prior to application of sealant							SC
Joints are completely filled.							SC
Nonsag sealants have been tooled to smooth surface							SC
Surfaces adjacent to joints are clean							SC
Sealant has cured according to manufacturer's recommendations and is ready for testing.							SC
Window Glazing							
Each unit is permanently labeled on spacer or on one pane.							GLC

Check Windows & Doors Components ->	Hardware	Sheet metal	Sealants	Glazing	Framing	Jams & Thresholds	**Contr.**
Visual characteristics, such as pattern, bow, and roll wave distortion are uniform.							GLC
Temporary labels have been removed. No tape or labels have been applied to glazing.							GLC
Installed glazing is clean.							GLC
Wood Doors							
Color, quality and finish are with acceptable color range							GLC
Doors units are square, plumb, level, and true to line, without warp or rack of frames or sash. Proper support is provided and units are anchored securely in place.							GLC
Masonry surfaces are dry and free of excess mortar, sand and other construction debris.							GLC
Rough or masonry opening is correct with required clearance for proper installation of exterior doors							UMC LVC GLC
Metal surfaces are dry, clean, free of grease, oil, dirt, rust and corrosion, and welding slag, without sharp edges or offsets at joints.							GLC
Doors are plumb, level, and true to line, without warp or rack of frames or sash. Proper support is provided and units are anchored securely in place.							GLC
Jam members and thresholds members have been set in a bed of sealant or with joint fillers or gaskets to provide weather tight construction.							GLC SC
Interior drains adjacent to ADA thresholds are plumbed to drainage plane per contract documents Weep holes are open and free of debris or blockages							LVC GLC
Door Glazing							
Each unit is permanently labeled on spacer or on one pane.							GLC
Visual characteristics, such as pattern, bow, and roll wave distortion are uniform.							GLC
Temporary labels have been removed. No tape or labels have been applied to glazing.							GLC
Installed glazing is clean.							GLC

Check Windows & Doors Components ->	Hardware	Sheet metal	Sealants	Glazing	Framing	Jams & Thresholds	**Contr.**
Final							
Report completed with this checklist attached							GC
Finished surfaces are clean and not discolored.							GC

- ***The checklist items of Part 3 are all successfully completed for given trade.___ YES ___ NO***

4. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check Windows & Doors Components->	Masonry	Limestone Veneer	Sheet metal	Sealants	Windows	Glazing	**Contr.**
All seals and joints are tight.							GC
System is waterproof as specified.							GC
Windows/doors and wood surfaces are clean. Hardware and other moving parts are lubricated.							GC
Windows/doors and hardware have been adjusted to operate smoothly and close tightly.							GC

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

END OF CHECKLIST

Annex M.3:
Example Construction Checklist for Windows and Doors

Commentary: This sub-annex provides an example of a construction checklist for windows and doors.

Credits: The example checklist contained on the following pages has been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

Annex M.3:
Example Construction Checklist for Windows and Doors

Commentary: This sub-annex provides an example of a construction checklist for windows and doors.

Credits: The example checklist contained on the following pages has been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

Annex M: Construction Checklists

Commentary: This annex is intended to provide information about checklists about the building exterior enclosure that are available form various sources. A number of these checklists are protected by copyright, so we are not re-producing them here. For such checklists we provide citations for the reader to use to obtain the checklists from the organizations that have published them.

In addition, we are including in sub-annexes selected pre-functional checklists that have been developed by members of the GL 3-2006 development committee. When applying the content provided in these sub-annexes the reader is encouraged to apply the checklist formats provided in Guideline 0-2005, Annex M. There are related test sub-annexes in Annex U below.

There are 3 sub-annexes to this annex that contain example construction checklists:

- M.1 – This sub-annex consists of 10 Construction & Industry Checklists compiled over time by McCarthy Building Companies, Inc. and assembled and formatted for this document by Bill Nash of McCarthy. These include:

  (1) Construction & Industry Checklist for *Waterproofing*, *07100*, Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (2) Construction & Industry Checklist for *EIFS*, *07240*, Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (3) Construction & Industry Checklist for *Commercial Low Slope Roofing Systems, 07500,* Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (4) Construction & Industry Checklist for *Flashing and Sheet Metal, 07600,* Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (5) Construction & Industry Checklist for *Joint Sealers, 07900,* Division 7, Thermal and Moisture Protection, Jan. 1, 2002.

  (6) Construction & Industry Checklist for *Entrances and Storefronts, 08400,* Division 8, Doors and Windows, Jan. 1, 2002.

  (7) Construction & Industry Checklist for *Windows, 08500,* Division 8, Doors and Windows, Jan. 1, 2002.

  (8) Construction & Industry Checklist for *Skylights, 08600*, Division 8, Doors and Windows, Jan. 1, 2002.

  (9) Construction & Industry Checklist for *Glazing, 08800*, Division 8, Doors and Windows, Jan. 1, 2002.

  (10) Construction & Industry Checklist for *Glazed Curtain Walls, 08900*, Division 8, Doors and Windows, Jan. 1, 2002.

- M.2 – Pre-functional Checklist for Building Envelope (Exterior Enclosure) System.
- M.3 – Pre-functional Checklist for Windows and Doors.

Credits: The following persons and organizations have provided materials for this annex and its sub-annexes:

- Sub-annex M.1 has been provided by Bill Nash of McCarthy Building Companies, Inc.
- Sub-annexes M.2 and M.3 have been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

M-1 Citations of Available Construction Checklists

The following is a list of citations of available construction checklists from other sources, organized by type of element of the building exterior enclosure.

Good Painting Practice: SSPC Painting Manual. The Society for Protective Coatings. Vol. 1, 4th ed. P. 545-551.

Manual for Inspection and Maintenance of Build-Up and Modified Bitumen Roof Systems: A Guide for Building Owners. Asphalt Roofing Manufacturers Association and National Roofing Contractors Association. P. 16-22.

Masonry Inspection Checklist. TMS Construction Practices Committee. The Masonry Society, Boulder, CO. 2004.

Portland Cement Plaster Stucco: Resource Guide. Northwest Wall & Ceiling Bureau. P. 178-183.

Annex M.2:
Example Construction Checklist for
Building Envelope System

Commentary: This sub-annex provides an example of a construction checklist for the building envelope (exterior enclosure) system. .

Credits: The example checklist contained on the following pages has been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

Construction Checklist

BUILDING ENVELOP SYSTEM

Components included: ___ unit masonry, ___ limestone veneer, ___ cast stone, ___ sheet metal flashing & trim, ___ roof, ___ joint sealants, ___ wood windows/doors

1. Submittal / Approvals

Submittal: The above components and systems integral to them are complete and ready for testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This construction checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ___ List attached.

Sealant Contractor	Date	Glazing Contractor	Date
Ext. Limestone Veneer Contractor	Date	Sheet Metal Contractor	Date
Masonry/Cast Stone Contractor	Date	Steel Fabricator	Date
General Contractor	Date	Roof Contractor	Date

Construction checklist items are to be completed as part of installation & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and installation procedures or reporting requirements.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- Contractors' assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CxA = commissioning agent, GC = general contractor, LVC = limestone veneer/sheet metal contractor, SC = sealant contractor, GLC = glazing contractor, UMC = masonry/cast stone/sheet metal contractor, RC = roof contractor, SMC = sheet metal contractor

Approvals: This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent	Date	Owner's Representative	Date

2. Requested documentation submitted (filled out by CxA)

Building Envelope Component-> Check	Masonry	Limestone Veneer/ Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Manufacturer's cut sheets								
Installation details								
Manufacturer's requirements								
Shop drawings showing attachment and details grills & louver								
Architect of record has reviewed installation to see that placement is consistent with original design.								
Building envelop structural engineer of record has reviewed concentric connections between limestone and embeds and issued a letter of acceptance.								

- ***Documentation complete per contract documents for given trade............ ___ YES ___ NO***

3. Installation Checks (filled out by contractor)

Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______
Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______
Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______
Location: _______ Elevation _______ Floor; _________ From grid line ________ to grid line _______

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
General Installation								
Building envelope component completed and cleaned per contract documents								GC
Dampproofing								
CMU are dry, free of dirt and excess mortar, sand and other construction debris before application of primer								UMC
Outside temperature is above 40 F during application of dampproofing								UMC
Dampproofing is 6-10 mils and pin hole free								UMC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Rigid Insulation								
CMU is plumb, level, true to line, and is free of obstructions that would inhibit good adhesion of insulation in dampproofing cement								UMC
Dampproofing is cured and ready for Insulation installation								UMC
Rigid insulation is securely bonded to CMU prior to exterior finish installation								UMC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								UMC
Roof								
Substrates and conditions under which ice & water shield are to be installed are dry, free of debris and satisfactory								RC
Ice & water shield lapped over flashing per contract documents								RC
Modified bitumen membrane laps per contract documents								RC
Cant strip installed at horizontal/vertical intersections per contract documents								RC
Metal flashing surfaces are dry, clean, free of grease, oil, dirt, and corrosion, and without sharp edges or offsets at joints.								RC
Lap joints are sealed in accordance with contract documents								RC
Flashing is installed in accordance with contract documents								RC
Limestone veneer								
Limestone is not discolored by contaminates								LVC
Anchors, dowels, fastenings, and hoisting fittings are properly installed Units are in good condition: not warped, distorted cracked, stained or otherwise damaged								LVC
Rigid insulation is securely bonded to CMU								LVC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								LVC
Flashing is installed in accordance with contract documents								LVC
Grouted joints are 3/8” ± 1/16” or less in width								LVC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Limestone is within specified tolerances ½" total height								LVC
Limestone corners are within specified tolerances 3/8" total height								LVC
Limestone within ¼" of plumb in 10 ft								LVC
Limestone is within ¼" of level in 20 ft, ½" in total run								LVC
Limestone is within ¼" of position or cross sectional dimension								LVC
Corner alignment of adjacent panels are within ± 1/32"								LVC
Steel anchors and attachments are in good condition								LVC
Limestone attachments are in line with structure attachment								LVC
Sufficient clearance between non grouted components to allow for proper backing rod and sealant installation								LVC
Cavity weep tubes are installed at sills, relieving angles, door and window heads, and embed joints								LVC
Horizontal weeps are at 5' centers or less, vertical cavity weeps at 20' or less								LVC
Weep holes are open and free of debris								LVC
Cast Stone								
Cast Stone is not discolored by contaminates								UMC
Anchors, dowels, fastenings, and hoisting fittings are properly installed. Units are in good condition: not warped, distorted, cracked, stained or otherwise damaged								UMC
Rigid insulation is securely bonded to CMU prior to placement of stone								UMC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								UMC
Flashing is installed in accordance with contract documents								UMC
Horizontal substrate is clean and free of debris prior to placement of drainage mat & waterproofing								UMC
Drainage mat and water proofing are installed according to contract documents								UMC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Vertical joints are ¼" unless otherwise indicated in contract documents								UMC
Cast Stone is within specified tolerances ±1/8" total height or width or length up to 2 ft								UMC
Cast Stone is within specified tolerances +1/16", -1/8" total length 2 ft to 5 ft								UMC
Cast Stone is within specified tolerances +1/8", -3/16" total length 5 ft to 10 ft								UMC
Cast Stone is within specified edge out of line tolerance of ±1/8"per 10 ft, ¼" maximum								UMC
Cast Stone corners are within specified tolerances 3/8" total height								UMC
Opening size ±1/2"								UMC
Opening location ±1/2"								UMC
Steel anchors and attachments are in good condition								UMC
Cast Stone attachments are in line with structure attachment								UMC
Ends of lugged sills and similar units are embed in mortar								UMC
Joints are raked to ¾" from face for pointing								UMC
Sufficient clearance between non grouted components to allow for proper backing rod and sealant installation								UMC
Excess mortar has been sponged off face								UMC
Rake joints have been allowed to set before application of pointing mortar								UMC
Cavity weep tubes are installed per contract documents								UMC
Weep holes are open and free of debris								UMC
Sheet metal flashing and trim								
Substrates and conditions under which sheet metal flashing and trim are to be installed are satisfactory								UMC LVC
Sheet metal complies with at least minimum specified thickness, weight, and grade.								UMC LVC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Exposed sheet metal is without excessive oil canning, buckling, and tool marks and is true to line and levels indicated, with exposed edges folded back to form hems.								UMC LVC
Surfaces were cleaned with no oils or foreign matter prior to sealing or joining together								UMC LVC
Lap joints are sealed in accordance with contract documents.								UMC LVC
Flashing between CMU & exterior finish is embedded in dampproofing and securely fastened								UMC LVC
Joints have been filled with sealant and metal formed to conceal sealant.								UMC LVC
Nonmoving seams in sheet metal and aluminum are fabricated with flat-lock seams								UMC LVC
Brick								
Brick color and texture matches mock-up								UMC
Anchors are properly installed								UMC
Rigid insulation is securely bonded to CMU								UMC
Rigid insulation joints are tightly butted to minimize moisture collection between joints								UMC
Flashing is installed in accordance with contract documents								UMC
Mortar color matches mock-up								UMC
Anchors and attachments are in good condition and correctly spaced								UMC
Brick is within ¼” of plumb in 10’ and within 3/8” per floor, and within ½” from base to roof line								UMC
Control joints are 25’ or less apart								UMC
Sufficient clearance between non grouted components to allow for proper backing rod and sealant installation								UMC
Cavity weep tubes are installed at sills, relieving angles, door and window heads, and imbed joints								UMC
Horizontal weeps are at 2’ centers or less, vertical cavity weeps at 20’ or less								UMC
Weep holes are open and free of debris								UMC

Check Building Envelope Components ->	Masonry	Limestone Veneer/Cast Stone	Sheet metal	Sealants	Glazing	Steel	Roof	**Contr.**
Joint sealants								
Joints are sufficiently spaced to allow proper application of backing and sealant								SC
Backing material has been installed in accordance with sealant manufacturer's requirements.								SC
Materials delivered in original containers or bundles with labels showing manufacturer, product name or designation, color, shelf life, and installation instructions.								SC
Joints are completely filled.								SC
Full contact is made with bond surfaces and there is a minimum 3/8" width adhesion area.								SC
Surfaces are clean and dry prior to application of sealant								SC
Non-sag sealants have been tooled to smooth surface								SC
Surfaces adjacent to joints are clean								SC
Sealant has cured according to manufacturer's recommendations and is ready for testing.								SC
Grills & Louvers								
Rough or masonry opening is correct and sill plate is level.								SMC
Grills/louvers are plumb, level, and true to line								SMC
Sill members and other members have been set in a bed of sealant or with joint fillers or gaskets to provide weather tight construction.								SMC
Final								
Report completed with this checklist attached								GC
Finished surfaces are clean and not discolored.								GC
Exterior wall has been cleaned in accordance with contract documents within 48 hours of substantial completion date								GC

- ***The checklist items of Part 3 are all successfully completed for given trade.___ YES ___ NO***

4. Operational Checks (These augment mfr's list. This is not functional performance testing.)

Check Building Envelope Components->	Masonry	Limestone Veneer	Sheet metal	Sealants	Windows	Glazing	**Contr.**
All seals and joints are tight.							GC
System is waterproof as specified.							GC
Brick, limestone, cast stone are clean.							GC
Cavity drains remove moisture effectively preventing water build-up in the cavity.							GC

- ***The checklist items of Part 4 are all successfully completed for given trade.___ YES ___ NO***

END OF CHECKLIST

Annex O: Systems Manual

Commentary: This annex is intended to provide an example of a Systems Manual.

A sample Systems Manual

There is currently 1 sub-annex that contains a sample of an overview of a Systems Manual including:

- o A list of players involved
- o An outline of the Systems Manual

Credits: The following persons and organizations have provided materials::

- o Sub-annex O.1 has been provided by Paul Totten of Simpson, Gumpertz & Heger Inc.

Annex O.1: Sample Systems Manual

Sample Systems Manual
Building Enclosure Commissioning

Project Name
Project Location (Enter full address)

Construction Duration: (Start Date) to (Date of Substantial Completion)

(Date of Issuance of Manual)

Design Team:

(List all members of the design Team, including all sub-consultants that impacted the envelope design (i.e. skylight or curtain wall consultant))

- Architect-of-Record
- Design Architect
- Engineer-of-Record
- Mechanical Engineer
- Civil Engineer
- Structural Engineer
- Lighting Consultant
- Site Consultant
- Landscape

Commissioning Authority:

(List all members of the commissioning authority Team, including all sub consultants that impacted the envelope design)

- Mechanical Commissioning Agent
- Building Enclosure Commissioning Agent
- Structural Commissioning Agent

Contractor Team:

(List all members of the contracting Team, including all sub-consultants and/or subcontractors that impacted the envelope design)

- General Contractor
- Roofing Subcontractor
- Window Subcontractor
- Waterproofing Subcontractor
- Curtainwall Subcontractor
- Skylight Subcontractor
- Façade Subcontractor (listed by wall type (i.e. brick, metal panel, precast, EIFS, stone veneer, etc.)
- Drywall Subcontractor
- Plumbing Subcontractor
- HVAC Subcontractor
- Electrical Subcontractor

Note: For all companies listed, include the following minimum information:

1. ***Company name and branch/local office and national address***
2. ***Contact Name(s), e-mail(s) and phone number(s)***
3. ***Web page***
4. ***General phone number and fax number***

Table of Contents

1. **General Contractor and Subcontractor Letters (Letters stating all contractual obligations met, including all requirements of the contract documents (including, but not limited to, the specifications and drawings)**

2. **Specifications**

3. **Addendums to the specifications**

4. **As-built specifications**

5. **CD Drawings**

6. **All addendums to the drawings**

7. **As-built drawings**

8. **All shop drawings (final copies; red-lined copies included in Appendix A of the Systems Manual)**

9. **Organized by specification section, the following information**

    a. **Summary sheet including:**
        i. **Product Used**
        ii. **Color or lot number**
        iii. **Manufacturer – address and contact number**
        iv. **Supplier – address and contact number**
        v. **Installer – address and contact number**
        vi. **Cross reference to all materials installed adjacent to product**
        vii. **Products Specified**

    b. **Warranty**
    c. **Maintenance manual from manufacturer**
    d. **Repair manual from manufacturer**
    e. **Submittals with all reviewer comments**

10. **CD or DVD-Rom of all project photos organized by date and all of the Building Enclosure Commissioning reports, Closeout Documents listed above, and Punch List with Status**

Sample Section under Item 9 – Products Used

Sealants – Specification Section 07920 – Joint Sealants

1. Joint Type I – Precast Panel to Precast Panel

a. **Product Used –** One part polyurethane sealant (Insert manufacturer name and product name)

b. **Color** - Limestone – (insert lot number)

c. **Manufacturer:**
XYZ Sealant Corporation
One Sealant Way
Rockville, MD 20850
Ph: 301.123.4567

d. **Supplier:**
Best Sealant Supplier Ever
Two Sealant Way
Rockville, MD 20850
Ph: 301.765.4321

e. **Installer:**
Great Caulking Company
One Contractor Way
Rockville, MD 20850
Ph: 301.987.6543

f. **Installed in contact with:**
   i. Precast panels (Section 03450 – Precast Concrete)
   ii. Kynar coated aluminum flashing (Section 07620 – Metal Flashing and Trim)

g. **Product Specified –** Same as product installed.

2. Joint Type 2 – Stone veneer to stone veneer

a. **Product Used –** One part polyurethane sealant (Insert manufacturer name and product name)

b. **Color** - Cream – (insert lot number)

c. **Manufacturer:**

XYZ Sealant Corporation
One Sealant Way
Rockville, MD 20850
Ph: 301.123.4567

d. **Supplier:**
Best Sealant Supplier Ever
Two Sealant Way
Rockville, MD 20850
Ph: 301.765.4321

e. **Installer:**
Great Caulking Company
One Contractor Way
Rockville, MD 20850
Ph: 301.987.6543

f. **Installed in contact with:**
   i. Stone Veneer (Section 044200 – Exterior Stone Cladding)
   ii. Kynar coated aluminum flashing (Section 07620 – Metal Flashing and Trim)

g. **Product Specified –** Same as product installed.

3. Joint Type 3 – Ribbon windows to stone veneer

a. **Product Used –** One part polyurethane sealant (Insert manufacturer name and product name)

b. **Color** - Cream – (insert lot number)

c. **Manufacturer:**
XYZ Sealant Corporation
One Sealant Way
Rockville, MD 20850
Ph: 301.123.4567

d. **Supplier:**
Best Sealant Supplier Ever
Two Sealant Way
Rockville, MD 20850
Ph: 301.765.4321

e. **Installer:**
Great Caulking Company

One Contractor Way
Rockville, MD 20850
Ph: 301.987.6543

f. **Installed in contact with:**
   i. Stone Veneer (Section 044200 – Exterior Stone Cladding)
   ii. Kynar coated aluminum flashing (Section 07620 – Metal Flashing and Trim)
   iii. Ribbon Windows (Section 085113 - Aluminum Windows)

g. **Product Specified –** Same as product installed.

4. **Joint Type 4 – Ribbon windows to precast panels**

   a. **Product Used –** One part polyurethane sealant (Insert manufacturer name and product name)

   b. **Color** - Cream – (insert lot number)

   c. **Manufacturer:**
   XYZ Sealant Corporation
   One Sealant Way
   Rockville, MD 20850
   Ph: 301.123.4567

   d. **Supplier:**
   Best Sealant Supplier Ever
   Two Sealant Way
   Rockville, MD 20850
   Ph: 301.765.4321

   e. **Installer:**
   Great Caulking Company
   One Contractor Way
   Rockville, MD 20850
   Ph: 301.987.6543

   f. **Installed in contact with:**
      i. Precast panels (Section 03450 – Precast Concrete)
      ii. Kynar coated aluminum flashing (Section 07620 – Metal Flashing and Trim)
      iii. Ribbon Windows (Section 085113 - Aluminum Windows)

   g. **Product Specified –** Silicone sealant (Insert manufacturer name and product name)

One Part Polyurethane Sealant – Product Warranty – Manufacturer's Warranty

Attach manufacturer's material warranty.

One Part Polyurethane Sealant - Labor Warranty – – General Contractor’s Warranty

Attach general contractor's labor warranty (may also be a warranty from the sealant subcontractor)

One Part Polyurethane Sealant – Maintenance Manual

One Part Polyurethane Sealant – Submittals with Comments

Annex R: Integration Requirements

This annex contains a list of issues both about the Integration of (1) the various elements of the Exterior Enclosure and (2) the Exterior Enclosure with other building systems. These issues are also cross-indexed within the matrices contained in Tables R1 and R2.

Commentary

This annex is intended to provide an overview of issues involved in the integrated design of exterior enclosure systems, and also the issues involved in the interaction of such exterior enclosure systems with other building systems.

The matrices shown in Tables 1 and 2 on the next few pages provide a summary of the many interactions involved and show how all of the issues relate to each other.

- Table R-1 shows the many issues and interactions to be integrated just within the exterior enclosure.
- Table R-2 shows the issues and interactions to be integrated between the exterior enclosure and the other building systems.

The pages following after Tables 1 and 2 provide a listing of the integration issues that have been identified.

This annex is by no means complete. This current version is a first draft to be expanded and refined over time.

Also, while this material is being presented here in hard copy format, we think that the best form of presentation of this material will be within interactive, object-oriented software that will allow all linkages among the issues to be more easily accessed than is possible in this current hard copy version.

Credits

This annex has been developed by David Altenhofen, with substantial input from Fiona Aldous, Wagdy Anis, and Joseph Deringer.

Key to general acronyms used in Tables 1 and 2

CxA = Commissioning Authority
DT = Design Team
PDP = Pre-Design Phase
DP = Design Phase
CP = Construction phase

Key to category codes used in Table 1

Where “X” represents “Exterior Enclosure”
Xa Air flow Control
Xv Water Vapor Flow Control
Xw Rain Penetration/Water Control
Xh Heat Flow Control
Xr Light, Solar, other Radiation Control
Xn Noise and Vibration Control

Xf Fire Control
Xs Structural Performance
Xd Durability
Xe Aesthetics
Xp Performance (Value)

Key to category codes used in Table 2

DL Daylighting Integration
I Interiors
Va Value (thermal & visual comfort, productivity, energy savings, etc)
V Ventilation
H HVAC
El Electrical
Du Durability
En Energy Saving
P Performance
C Control System/ Building Automation
F Fire Protection
S Structural
N Acoustical (and Noise)
R Comments, Remarks

Table R-1 goes here

Table R-2 goes here

R.1 Exterior Enclosure Issues

R.1.1 Air Flow Control

R.1.1.1 Air Barriers

Xa.1 **Air Barrier:** Air barriers are an extremely important component in the control of the separation of the internal and external air masses, with resulting impacts on durability, indoor air quality, and energy consumption. Air barrier detailing must be complete around the full perimeter of exterior enclosure and across all systems.

The Commissioning Authority should verify the following:

- o Design Phase: Design Phase: The Design Team has selected systems with appropriate air barriers and permeance for each component of the enclosure, and has detailed continuity of air barrier across joints between the air barriers.
- o Construction Phase: Test air leakage through exterior systems.

Xa.2 **Air Barrier Penetrations:** Numerous penetrations are likely through the air barrier, including MEP systems, anchorage devices for cladding, or electrical outlets and other penetrations of interior faces of exterior walls.

The Commissioning Authority should verify the following:

- o Design Phase: That the Design Team has reviewed the extent of penetrations and provided detailing, including:
  - Sleeves with integral flanges at mechanical penetrations,
  - Means of sealing at electrical conduit and plumbing piping penetrations.

  In addition, That the Design Team has evaluated the type of anchorage and substrate to which the anchors are being installed to or through to determine likelihood for future voids to be created in the air barrier due to future actions of the wall, such as movement due to thermal cycling.
- o Construction Phase: Verify that sealing of penetrations are properly installed. Periodically inspect penetrations for proper sealing and integration with the air barrier.

Xa.3 **Air/Vapor Barriers at Intersection of Structural Systems:** Continuity of air barrier and/or vapor retarder may require special detailing at intersections of foundations with footings/walls/columns and at roof/parapet. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer so that details allow both adequate structural connections, accommodate movement and continuity of air/vapor barriers.
- o Construction Phase: verify that submissions for foundation and structural systems are coordinated with requirements for air/vapor barrier. Inspect installation of structural systems to allow subsequent installation of air/vapor barrier.

See also: Structural Performance, Vapor Control.

Xa.4 Roof to wall interface for Air Barrier: Often wall cladding will continue above the top of the roof slab, at which point the closure between the edge of the roof and the wall system must be remain continuous. A separate parapet wall constructed on top of the roof slab is recommended and a movement joint detailed to address the anticipated differential movement between the roof slab and the curtain wall. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has detailed wall cladding and parapet wall for anticipated floor slab deflection and wall movement.
- o Construction Phase: Detailing and construction provides adequate accommodation for movement and continuity of air barrier from wall to roof system.

Xa.5 Air Barrier Wind Loading: Air barrier layer must be capable of supporting appropriate positive and negative loading, even though it frequently is buried within the exterior enclosure assembly. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has properly identified air barrier layer and coordinated with structural engineer to adequately support air barrier against wind loading.
- o Construction Phase: air barrier system is installed to resist wind loading per design prior to being covered by subsequent construction. Test for fastener spacing and pull out resistance and wind load resistance.

See also: Air and Vapor Barrier Issues, Security/ Blast Issues

Xa.6 Air/Vapor Barrier: Exterior enclosure system will most likely include an air barrier, a vapor retarder or both. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has properly identified layers in assembly that act as rain screen, air barrier, vapor barrier, wind load support, etc.
- o Construction Phase: Inspect to verify that layers as identified in design are constructed to perform the required function, i.e. that vapor permeable air barriers are not substituted with a membrane that is also a vapor barrier.

See also: Vapor Barrier, Rain screen

Xa.7 Internal Air Pressure: Windows or other vents left open, or an air-leaky envelope during periods of high wind can create positive internal pressure in addition to normal suction loads, thus creating higher stresses on roof, air barrier and other membrane systems. The condition gets more extreme as the building gets taller.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team The Design Team has determined appropriate loading criteria, selected and detailed systems to withstand the loading. The criterion is included in specifications for membrane performance.

- o Construction Phase: Periodically test for thickness, installation and adhesion of material.

Xa.7a Air/vapor Seal: Interior face of exterior wall may need special detailing. Particularly at electrical outlets and other penetrations, if gypsum wallboard or a membrane directly under is the air barrier and/or vapor retarder.

CxA should verify that:

- o Design Phase: The Design Team (DT) has provided the special detailing as appropriate for the design.
- o Construction Phase: The details developed during design have been incorporated into the building exterior enclosure.

R.1.1.2 Natural Ventilation

Xa.8 Natural Ventilation: Natural ventilation via operable windows as a primary ventilation system during occupied periods is most effective in relatively mild climate conditions, such as in Mediterranean coastal climates or at high altitudes near the equator. Natural ventilation may also be a primary ventilation system during occupied periods in other more extreme climates during certain milder periods of the year, or where extended comfort conditions are accepted. As a passive cooling strategy, natural ventilation relies solely on air movement to cool occupants.

The Commissioning Authority should verify the following:

- o Pre-design Phase: that acceptable ranges and variations in comfort conditions have been defined and have accepted by the owner.
- o Design Phase: The Design Team has allowed for healthy and code required ventilation, and for adequate manual or automatic control of the ventilation system through operable windows or other openings.
- o Construction Phase: Operable windows are functional and mechanical systems function as designed.

See also: hybrid ventilation, night cooling ventilation.

Xa.9 Hybrid Ventilation: Natural ventilation during occupied periods is most effective in relatively mild climate conditions. In more extreme climate conditions, direct introduction of hot, cold or humid exterior air may not be desirable. Under such climate conditions, except in residential occupancies, mechanical ventilation will probably still be required in addition to natural ventilation. As a passive cooling strategy, natural ventilation relies solely on air movement to cool occupants.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has allowed for healthy and code required ventilation, either through operable windows or mechanical systems. Systems that rely on operable windows should be reviewed for effectiveness if it is possible they won’t be used during extreme cold or heat to avoid high energy costs or uncomfortable side-effects.
- o Construction Phase: Operable windows are functional and mechanical systems function as designed.

See also: natural ventilation.

Xa.10 Manual Control of Natural Ventilation: To be safe and effective, natural ventilation requires either routine human intervention or an automated operating system. Natural ventilation without a mechanized control system lacks the ability to tightly control interior temperature and humidity. In this case, occupants must be willing and motivated to properly open and close vents to suit building schedule, weather conditions, and desired thermal comfort. The Commissioning Authority should verify the following:

- o Design Phase: (1) The Design Team has reviewed pros and cons of various control systems, and understands occupant requirements and (2) the selected ventilation control system and its operation meets the Owner's Project Requirements.
- o Construction Phase: Verify that if the Owner accepts a manual control system, that the occupants and owner's staff have received training for operation of the natural ventilation manual controls and the relationship to other building operations. Otherwise, verify that if Owner requires an automated system, that it is periodically tested and a final acceptance test is performed.

Xa.11 Night Ventilation Cooling: Night ventilation might help maximize effectiveness of daily heat storage of thermal mass by using overnight ventilation to cool the mass.

If this strategy is being considered, the Commissioning Authority should verify the following:

- o Design Phase: The Design Team has analyzed the cost/benefit of night cooling and incorporated appropriate features into the design.
- o Construction Phase: Operable components provide for proper functioning and Sequence of Operation.

Xa.12 Natural Ventilation with Double Facades: Double façade might allow maximum balance of user-controlled natural ventilation and system control of ventilation system, especially in taller buildings where consistently higher exterior wind speeds would not otherwise allow directly operable windows. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated cost/benefit of ventilating from cavity of double façade and if included the ventilation scheme provides adequately for occupant comfort, health and code conformance.
- o Construction Phase: Operable portions of the double façade required for the ventilation functions properly.

See also: Double Facades and rain-water control, heat flow control, thermal comfort, acoustics, daylighting, glare reduction, visual comfort, and integration with lighting and HVAC systems

Xa.13 Increased Ventilation: The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has allowed for healthy and code required ventilation, either through operable windows or mechanical systems. Systems that rely on operable windows should be reviewed for effectiveness if it is possible they won't be used during extreme cold or heat to avoid high-energy costs.
- o Construction Phase: Operable windows are functional and mechanical systems function as designed.

R.1.1.3 Biological/Chemical Isolation

Xa.14 Exhaust Re-entrainment: Location and types of air intakes and exhausts need to be studied for security and to avoid re-entrainment of contaminants into the interior environment. The Commissioning Authority should verify the following:

- o Design Phase: Design Phase: The Design Team has evaluated wind-wake and re-entrainment. For important projects, expert consultant's recommendations as a result of wind tunnel testing or modeling for locating air intakes and exhaust has been incorporated into project.
- o Construction Phase: verify that exhaust fans and stacks comply with design and test performance.

Xa.15 Differential Pressure: The building may require differential pressurization schemes to control direction of airflow in order to either contain bio-contamination or to exclude contaminants infiltrating building. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated building pressurization scheme and has incorporated requirements into enclosure design to resist differential pressure.
- o Construction Phase: differential pressure is verified in Testing and Balancing.

See also: Air barriers, since pressurization schemes are better controlled when air barriers produce tighter, less leaky enclosures.

R.1.2 Water Vapor Flow Control

R.1.2.1 Vapor Retarder

Xv.1 Vapor Barriers and Retarders: For walls and roofs, the need for vapor barriers or retarders should be evaluated by study of interior and exterior environments and proposed designs of assemblies. For slabs supported by soil, vapor barriers with very low permeance must be included to avoid floor finish failures.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team The Design Team has performed adequate study, preferably using computer modeling such as WUFI, to determine need for vapor barriers or retarders.

- Design Phase: The Design Team The Design Team has included an under-slab vapor barrier by a manufacturer who has termination and penetration details.
- Construction Phase: Vapor retarder is installed to comply with design. Periodically inspect vapor barrier, especially terminations, top and base joints, seams and penetrations.
- Construction Phase: No sand layer has been included on top of slab vapor barrier.

Xv.2 Vapor Barrier and Retarder Location: Location of vapor retarder in enclosure assemblies must be studied for constructability and reliability.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed adequate study, preferably using computer modeling such as WUFI, to determine optimum location for vapor retarder within exterior enclosure.
- Construction Phase: Construction Phase: Vapor retarder is installed in location indicated on documents. Verify that other layers of enclosure are not improperly substituted and thus resulting in a significant change to the vapor resistance characteristics and drying potential of the enclosure system.

Xv.3 Continuity of Double Seals: Windows, doors and other penetrations must be designed for continuity of inner and outer lines of defense.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has included provisions for continuity of double seal in all exterior enclosure detailing.
- Construction Phase: Periodically inspect installation for conformance with documents. Test effectiveness of double seal by artificially violating outer seal and performing air/water infiltration tests to verify weeps are active in outer line of seals.

Xv.4 Face Seal of Penetrations: Windows, doors and other penetrations must be designed to allow proper seal to the face of the barrier.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has designed for adequate sealant joint sizes and profiles, compatibility of substrates, and integrated with flashings and adjacent systems.
- Construction Phase: Inspect to verify joint sizes are adequate, substrates are cleaned and primed, seals are properly installed and tooled. Periodically perform cut tests to verify installation and adhesion.

Xv.5 Double Vapor Barrier: Weatherproof face of barrier system may create a vapor retarder on the exterior side of the insulation.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed adequate study, preferably using computer modeling such as WUFI, to determine that enclosure system will dry out between precipitation events.

- o Construction Phase: Permeance of installed materials matches design.

Xv.6 Floor to Slab Detailing: Vapor barriers below concrete slabs-on-grade may have an impact on floor slab detailing and flatness/curling.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer so that details allow both adequate structural connections and continuity of vapor barriers.
- o Construction Phase: verify that submissions for foundation, slabs and structural systems are coordinated with requirements for vapor barrier. Inspect installation of vapor barrier for conformance with design, including sealing of joints and extensions of vapor barrier for subsequent connections to other barriers.

R.1.2.2 Self-Drying Assemblies

Xv.7 Drying Potential: Permeance of layers of envelope assemblies must be studied to allow drying.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has performed adequate study, preferably using computer modeling such as WUFI, to determine that enclosure system will dry out between precipitation occurrences.
- o Construction Phase: Construction Phase: Verify that permeance of installed materials matches design.

R.1.3 Rain Penetration/Water Control

R.1.3.1 Drainable/ Rain Screen Systems

Xw.1 Drainage Cavity: Cavity resulting from drainage plane can be used for air barriers, vapor retarders and insulation.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has adequately documented all layers of assembly and has allowed for proper detailing to drainage cavity.
- o Construction Phase: Periodically inspect to verify cavity drainage provisions are maintained. Test for water penetration to interior and effectiveness of drainage and flashing systems.

See also: air barriers, vapor retarders, heat flow control.

Xw.2 Louvers and Plenums. Louver selection for maximum water tightness is important, to reduce water and snow penetration. Verify that size and free area has been selected to avoid air speeds that promote entrainment of water and snow. Plenums behind louvers are subject to full design wind loads and must be designed as water-resistant construction. Floors or plenum bottoms must include drains, and be pitched to drain.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has selected water-resistant louvers, air speed below maximum recommended. Plenums are detailed for wind pressure, water tightness and drained.
- o Construction Phase: Inspect and water test louver systems.

Xw.3 Cantilevered Outer Wall: Heavier outer rain screen, such as brick veneer, require special detailing to support substantial distance outside of structural frame.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer to provide shelf angles, lintels, or other supplemental structural steel required to support the rain screen.
- o Construction Phase: verify installed structural supports comply with design.

Xw.4 Coordination of Adjacent Wall Systems: An exterior wall may be comprised of various wall-cladding designs, such as barrier, drainage cavity, or pressure equalized rain screen. Isolation at the interface of different wall systems should provide that air and moisture infiltration does not violate adjacent systems.

The Commissioning Authority should verify the following:

- o Design Phase: Design Phase: The Design Team confirmed the design intent of each wall system and provided necessary closures both horizontally and vertically to control the migration of air and moisture.
- o Construction Phase: Verify system isolation means for each system are installed correctly and are continuous.

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Xw.5 Protected Membrane Roofing or Waterproofing:
Roofing/waterproofing membrane is on the conditioned side of roof insulation, serving also as air barrier and vapor retarder. Because membrane is protected from UV, temperature and physical abuse properly designed and installed inverted roof systems can be some of the best performing.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has properly selected, detailed and specified the roof system, including tying system into air/vapor membranes at adjacent parapet and wall assemblies.
- o Design Phase: The Design Team has designed overburden for the wind uplift pressure.
- o Construction Phase: Inspection and appropriate testing regime, including bond tests, thickness testing, inventory management procedures, and flood or EFVM testing of completed system.

Xw.6 Roof Membrane: Roof membrane attachment must be coordinated with the structural deck type, slope and drainage. Provisions for expansion and control joints, transitions in roof deck, fire resistive requirements, wind uplift requirements and perimeter edge detailing should be coordinated.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has selected appropriate roof system and has detailed integration of roof system with adjacent walls, and incorporated provisions as outlined above.
- o Construction Phase: Inspect for installation and perform flood or EVFM testing, including vertical interfaces and flashings.

See also: Reflective Roofs, white roofs.

Xw.7 Wall Panel Integration with Roof Systems: transitioning from the panel to the roof slab / panel as parapet wall / panel seals and window washing equipment.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team flashing at top of panel to protect the panel-to-panel sealant joints at the top of the panel. Provide detailing at the roof to back side of panel transition, to accommodate differential movement between the panel and the concrete slab as required. Outline the anticipated movement if any.
- o Construction Phase: the continuity of roof to the panels; bridging the gap between the edge of the slab and roof, and the backside of the wall panel.

Xw.8 Wall Panel Integration with Fenestration / Fenestration Flashings: Panel profile and size of perimeter joints should account for the integration of flashings or fenestration system.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team perimeter seals are specified to be installed before the installation of windows for continuity at inside corner where difficult access for sealant installation. Flashings should be identified on the drawings and integrated with double lines of sealant to maintain a continuous air barrier. Flashings should incorporate air baffles to reduce migration of air through the weeps.
- o Construction Phase: Joints sizes and profiles are achieved and flashings are integrated with seals to maintain continuity of air and water seals.

Xw.9 Wall Panel Design at Openings: Wall panel designs usually incorporate openings for windows, louvers, doors etc in the overall design if the façade. It is important that the panel itself is designed to properly control rainwater and direct it away from the façade elements.

- o Design Phase: The Design Team design the panel to incorporate slope on horizontal portion of the panel, including window sills and top of parapet, drip edge at head of the underside of openings and projections etc.
- o CP verifies that panels incorporate all designed elements to control rainwater run-off and direct the water away from the façade.

Xw.10 Wall openings and Perimeter Seals: Various wall openings occur in cladding systems, such as fenestration and penetrations. These openings and adjacent enclosure systems must provide adequate joint size and substrate for proper joint width and depth, and substrate continuity and compatibility. Accommodations for movement of various materials should be incorporated in the design.

- Design Phase: The Design Team should design joint for adequate tolerances and specific material substrates.

CP verifies that cladding and systems maintain joint design. Periodically perform sealant joint inspection for conformance with designed joint width to depth ratios, adhesive and cohesive properties and tooled installation.

Xw.11 Protection from Freezing: Wet systems on exposed side of thermal envelope need protection.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has adequately designed insulation, heat tape and other protection from freezing.

Construction Phase: Periodically inspect for quality on installation.

R.1.3.2 Thin Barrier Systems

Xw.12 Reliability of Thin Barrier System: System evaluation may rely on unrealistic expectation of near perfect installation to deliver performance.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has disclosed to Owner the limitations of the system, probability of success, problems that may result from failure and other collateral damage.
- Construction Phase: If a more reliable rainwater system has been selected, verify that a thin barrier system is not substituted for other more reliable systems.

R.1.3.3 Mass Barrier Systems

Xw.13 Mass Walls: Large areas of mass wall water protection systems can limit the size of exterior openings. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has provided proper support for all openings in the exterior enclosure, especially large openings and openings are flashed and coordinated with the structural engineer.
- Construction Phase: Lintels and structural frames at openings comply with documents and are properly flashed including back leg and end dams, and integrated with the air barrier.

Xw.14 Double Lines of Sealant: Joints between wall barrier assemblies, such as precast concrete and glass fiber reinforced concrete panels (GFRC) and the like preferably should utilize a two-stage sealant joint system to improve long-term performance. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has documented double line of sealant between joints of panels and between panels to adjacent construction. Air space between joints must be separated into compartments and weeped.
- o Construction Phase: Sealant products comply with specification, and that installation complies with specifications, particularly requirements to cure inner sealant before installing outer line. Selectively remove outer line of sealant to verify presence of inner line.
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Xw.15 Smaller Windows: Reduce size of windows resulting from massive façade may reduce daylighting and therefore increase energy usage. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has performed detailed analysis of the impact of energy required for daylighting versus energy saved by massive wall and the visual quality of the spaces resulting from smaller windows.
- o Construction Phase: Verify that materials are not changed from design and that solar shading or other devices are properly installed.

R.1.3.4 Below-grade Systems/ Foundations

Xw.16 Waterproofing System: High water tables require careful selection of waterproofing and sub-drainage systems based on hydrostatic head, required reliability, excavation system (sheeting/ shoring or open cut), accessibility for repair, cost, local trades, and coordination with foundation. Failure of waterproofing systems is generally due to workmanship flaws, not material shortcomings. Workmanship flaws are a statistical probability. The ability to access and repair waterproofing is important, and due consideration should be given to accessible negative side systems.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has considered optional systems and selected the most reliable and best value; CD's include complete specification and details coordinated with MEP systems as required.
- o Construction Phase: Periodic inspection program with appropriate testing of system performance characteristics (i.e. bond, installed thickness) and total system performance (i.e. flood test or Electric Field Vector Mapping (EFVM))

Xw.17 Waterproofing Details: Below-grade joints and penetrations of foundation wall become crucial waterproofing details.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural/MEP engineers and has detailed for making watertight and appropriate drainage.

- o Construction Phase: Periodic inspection and testing of waterproofing membranes, drainage systems, joints and tie-in details.

Xw.18 Waterproofing Transition to Wall System: Various below grade waterproofing systems may be installed, each requiring a transition to an above grade wall system. Barrier wall design must be carefully detailed and curbs at barrier walls are recommended for proper integration of the two systems.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has provided transition details that integrate and complement each other at below to above grade interface.
- o Construction Phase: Verify that construction sequencing facilitates the proper installation and coordination of the systems to obtain a water and airtight assembly.

Xw.19 Below-grade Spaces: Use of below grade space may need to be minimized or eliminated because of possibility of leaks.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated the building layout with OPR and if below-grade space susceptible to water leaks are included in project Owner is aware of risks.
- o Construction Phase: intended use of below grade spaces is not inappropriately changed.

Xw.20 Sub-Drainage: Sub-Drainage and pumping systems may be required.

CxA should verify that:

- o Design Phase: The Design Team (DT) has coordinated with structural engineer and geotechnical engineer for requirement for sub-drainage and with plumbing engineer and electrical engineer for actual piping/pumping system and emergency power supply.
- o Construction Phase: Verify that all required submittals are coordinated among various trades required to provide a functioning sub-drainage system.

R.1.4 Heat Flow Control

R.1.4.1 Increased Enclosure Insulation (Reduce Heat Losses)

Xh.1 Insulation Thickness: Increasing insulation thickness is most effective for buildings having opaque enclosure heat loss as a major portion of the energy load. Increasing insulation has the most positive effective on structures with HVAC substantially driven by heat loss/gain loads, such as house or small structures. From an energy perspective, adding insulation is not as effective on structures with high internal loads, i.e. increasing insulation values by 50% on building with skin loss/gain of only 5% of the total energy usage may result in an inconsequential savings of energy. Enclosure assembly may need to be thicker to accommodate increased thickness of insulation.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has determined the minimum insulation required by energy code, determined the effective additional thickness and coordinated with building energy load modeling.
- o Construction Phase: Periodically check insulation type, thickness and installation.

Xh.2 **Avoid Thermal Bridging:** Thermal bridging can severely reduce the effectiveness of insulation. For example, thermal bridging across steel studs in a wall can reduce effectiveness of insulation between the studs by 50%. A layer of continuous insulation on the exterior of over steel-framed walls minimizes thermal bridging.

Where thermal bridging potential occurs within any potion of the exterior enclosure, the Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated the payback for increased insulation to offset thermal bridging in relationship to the total energy consumption of the building.
- o Construction Phase: Verify submittals and construction conforms to thermal bridging reduction aspects of the design.

R.1.4.2 Thermal Mass

Xh.3 **Thermal Mass:** Thick walls and floors of substantial mass can be effective for passive heating and passive cooling in climates with large and consistent day/night temperature shifts. Massive materials are typically not good insulators and do not perform well in climates with consistently hot or cold temperatures for long periods of time. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated the thermal time lag of the massive assembly.
- o Construction Phase: Thickness and type of material.

R.1.4.3 Structure Outside of Thermal Enclosure

Xh.4 **Increased Structural Movement:** Structure located outside of thermal enclosure causes increased movement and thermal stresses.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer for extra movement of structure and required thermal protection of structure to minimize that movement.
- o Construction Phase: structure is insulated or other wise protected from thermal cycling prior to installation of weatherproof covering.

Xh.5 **Heat sink effect:** Structure outside of the line of the exterior enclosure may act as a large heat sink. In extreme climates the problem is larger. For buildings that require substantial heating or cooling, the heat sink affect could reduce energy consumption if weather conditions are suitable and the heat exchanges between source and sink are properly designed.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has evaluated both the energy gain and loss through structural thermal bridges, how that loss or gain affects the total load for the structure and the possibility of uncontrolled condensation.
- Construction Phase: Verify submittals and construction conforms to design.
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Xh.6 Structural Thermal Bridges: In extremely cold climates, locating structure outside of thermal envelope can be difficult to control. Detailing the air barrier penetration is a challenge. Points where structure extends through the exterior enclosure require special detailing to allow movement, minimize thermal breaks, stop air leakage and prevent uncontrolled condensation. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has properly detailed joints, insulation, air barrier and vapor barrier.
- Construction Phase: Conformance with detailing, and test for air/water leaks.

R.1.4.4 Control Solar Gain

Xh.7 Reflective Radiant Barrier: Reflective radiant heat barriers are most effective in hot climates and at high temperatures. Since they work only when adjacent to air spaces, air cavities will need to be placed within or adjacent to the enclosure assemblies to allow the reflective barriers to function.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has determined the proper orientation for the radiant barrier and incorporated an air cavity.
- Construction Phase: Barrier is oriented properly and adjacent cavity is in place.

R.1.5 Light, Solar and Other Radiation

R.1.5.1 Daylighting

Xr.1 Glazing Areas and Visible Transmittances for Daylighting: daylighting penetration into occupied spaces is strongly related to the Effective Aperture of vertical glazing and roof openings. For vertical windows, Effective Aperture (EA) is visible transmittance times the window-to-wall ratio (EA = Tvis X WWR). For example, from side lighting with normal window head heights, an EA>= 0.15 to 0.3 will provide adequate daylighting quality within the perimeter zone. EA greater than 0.3 will result in a negative energy impact, and would need to be justified for other reasons than either daylight benefit or energy savings.

Thus, if the glazing visible transmittance is say Tvis=0.50, then 30% to 40% glazing area is probably sufficient for daylighting. If larger glazing areas are used it is probably for aesthetic or other reasons.

And, if the glazing visible transmittance is say Tvis=0.15, then a glazing area of almost 100% would be needed for strong daylighting benefits.

Thus, for daylighted spaces the Commissioning Authority should verify the following:

- During design that exterior enclosure designer has specified an appropriate balance of WWR and glazing visible transmittance, consistent with NFRC or similar rating procedures.
- During construction of the exterior enclosure, that the glazing that is installed meets the specified range of visible transmittance.

See also: Heat flow control

Xr.2 **Light Shelves:** Light shelves or other devices may be desired to increase the area of building floor area accessible to daylight from sidelighting with vertical fenestration.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has analyzed light shelf or other techniques for increased penetration of light into interior.
- Construction Phase: Light shelf or other techniques are of same materials and profile as indicated in drawings.

R.1.5.2 Shading

Xr.3 **External Shading:** External-shading devices can greatly reduce solar heat gain, glare and excessive contrast from large glazed areas.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has evaluated shading devices for effectiveness of shading devices to reduce solar heat gain and glare.
- Construction Phase: Shade is of same materials and profile as indicated in drawings.

See also: HVAC sizing.

Xr.4 **External Shading and Aesthetics:** External shading devices have significant impact on aesthetics, and shading design should have positive impact on mechanical system sizing to avoid being easily deleted from project.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has selected a shading device design to control glare and reduce mechanical loads. Devices are coordinated with wall cladding systems to verifty that attachment details do not violate air barrier or barrier cladding.
- Construction Phase: Shading devices not omitted from project without redesigning the mechanical system. Detailing and installation of the shading devices retains continuity of weather tight exterior enclosure.

Xr.5 Overshading from Glazing: Heavily tinted glass may permanently detract from visual and psychological effect of glazed areas.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has modeled or mocked-up glazing to verify interior light levels.
- o Construction Phase: Individual elements of glazing design are not changed which could reduce interior light levels beyond owner's expectations.

Xr.6 Shading Tradeoffs: Study required maximizing effectiveness of external fixed, external active, and internal operable shading devices to limit peak solar gain loads while still allowing solar gain without excess glare or overheating of occupied spaces at times of maximum enclosure heat loss.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has sufficiently analyzed impact of shading to optimize energy efficiency.
- o Construction Phase: Shading system is installed to match design assumptions. Verify dimensions, layout and materials of the shading devices.

Xr.7 Internal Shading: Blinds or shades with local occupant control may be effective for shading. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has analyzed impact of interior shading on heat gain/loss and requirements to automate the operation of the blinds to realize savings or dependence on occupant or staff control.
- o Construction Phase: if a motorized and automated system was included in design and was basis for reduction in mechanical system, verify that system is not value engineered out. Test operation of automated system for conformance with required sequence of operations.
- o Occupancy Phase: train occupants on proper use of shading devices.

R.1.5.3 Glare Control

Xr.8 Glare Control with Increased Fenestration: Glare control and shading become more important with increased glazing area. The Commissioning Authority should verify the following, especially for fenestration Effective Apertures greater than 0.15:

- o Design Phase: The Design Team has considered glare factor and impact on inhabitants and adjacent buildings.
- o Construction Phase: Review and verify systems to control glare.

See also: DL-1 Glazing area and visual transmittance for Daylighting

Xr.9 Active External Shading: Active External shading devices can greatly reduce glare and excessive contrast from large glazed areas during sunny days and periods of high sky luminance (brightness) or from reflected glare from snow or water. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated shading devices for effectiveness of reducing glare.
- o Construction Phase: Verify that shading devices is of same materials and profiles as indicated in drawings and specifications.

Xr.10 Operable Internal or Integral Shading: Operable shading devices either interior to or between the glazed surfaces can be controlled by occupants to greatly reduce glare and excessive contrast from large glazed areas during sunny days and periods of high sky luminance (brightness) or from reflected glare from snow or water. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated operable internal or integral shading devices for effectiveness of reducing glare.
- o Construction Phase: Verify that shading devices is of same materials and profiles as indicated in drawings and specifications.

R.1.5.4 UV Control

Xr.11 UV-Resistant Glazing: Light fades and deteriorates dyes and materials made from cellulose, and natural organic fibers. Ultra-violet filtration improves resistance to fading. A discussion of goals and exposure targets should be held. Windows and skylights may be eliminated or greatly reduced. Windows and skylight systems must incorporate laminated glass with a Poly Vinyl Butyral (PVB) interlayer.

The Commissioning Authority should verify the following:

- o DP: The Design Team has selected and specified systems that incorporate PVP interlayer.
- o CP: Verify UV level lower than targets established by testing.

R.1.5.5 Photovoltaic Generation

Xr.12 PV Photo-voltaics: Integration of PV panels into the enclosure may require careful accommodation of building orientation to maximize effectiveness.

CxA should verify that:

- o Design Phase, the DP has studied PV panels for optimum orientation and performance.
- o Construction Phase, PV panels are installed to match design. Test for PV panel output.

R.1.5.6 Radio/Electromagnetic Interference Control

Xr.13 Shielding: Exterior enclosure must be designed to allow installation of a continuous envelope of shielding.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has documented a continuous system.

- o Construction Phase: System is installed in compliance with documents, test shielding system.

Xr.14 Shielding: All exterior openings including windows, mechanical louvers, and other penetrations may need to be minimized and special detailing will be required for shielding.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has detailed all windows, doors, louvers, ducts, pipes, conduits and other penetrations.
- o Construction Phase: Exterior enclosure and HVAC systems are installed in compliance with documents and approved submittals.

R.1.5.7 Green Roof, White Roof

Xr.15 Green Roof: Roof membrane must be more dependable, similar to waterproofing, because access for repairs requires removing overlying plant materials, soil and insulation. Single ply membranes that rely on adhesive or taped joints are not appropriate.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has selected the most dependable roof membrane and has specified proper protection layers and root barriers.
- o Design Phase: Roof drains and flashings have an adjacent plant-free area.
- o Construction Phase: Inspect for installation of protection measures.
- o CP. Test membrane before and after installation of overburden (EFVM).

Xr.16 White Roof (Reflective Roof): High Emissivity, white, or reflective roofs are desirable for energy conservation, except where glare can result. This strategy is effective across a reasonably broad range of climates and increases in effectiveness as cooling loads and roof areas increase.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has selected and detailed an appropriate reflective roof system.
- o Construction Phase: Inspect and test roof installation for reflectivity.

See also: Roof Membrane in rainwater control.

R.1.6 Noise and Vibration Control

R.1.6.1 Acoustical Control

Xn.1 Acoustic Isolation, High Frequency: High frequency isolation requires multiple layers of differing thickness and mass, resiliently mounted.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated acoustic spectrum attenuation requirements and selected system that will provide

appropriate in-place performance. Include roofs for overhead sources.
- o Construction Phase: Test early portion of installed system to verify performance, periodically inspect and test remainder of system.

Xn.2 Acoustic Isolation, Low Frequency: Low frequency isolation requires mass.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has evaluated acoustic spectrum attenuation requirements and selected system that will provide appropriate in-place performance. Include roofs for overhead sources.
- o Construction Phase: Test early portion of installed system to verify performance, periodically inspect and test remainder of system.

Xn.3 Acoustic Isolation, Penetrations: Louvers and similar penetrations through enclosure will need special detailing for acoustic isolation.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has included sound attenuators, baffling, absorption and other acoustic provisions required to meet mechanical requirements while maintaining acoustic isolation. .
- o Construction Phase: Periodically check louver, plenum and mechanical system submittals and installation to verify special isolation provisions are installed per design. Field test attenuation at start of construction and again at end if critical.

Xn.4 Acoustic Windows: Windows and glazing may require special details and multiple layers of special glass

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has evaluated acoustic spectrum attenuation requirements and selected system that will provide appropriate in-place performance.
- o Construction Phase: test early portion of installed system to verify performance, Periodically inspect and test remainder of system.

See also: heat flow control, daylighting, glare control, and vibration control

Xn.5 Double Façade Acoustic Benefits: Double facades may be desirable when acoustics are a prime consideration.

CxA should verify the following:
- o Design Phase: The Design Team has selected double facades to satisfy appropriate owner acoustic requirements.
- o Construction Phase: Tests for acceptable acoustic performance are conducted and documented for installed double façade system.

See also: Double Facades and natural ventilation, rain-water control, heat flow control, thermal comfort, daylighting, glare reduction, visual comfort, and integration with lighting and HVAC systems.

R.1.7 Fire Control for Exterior Enclosure

Xf.1 Fire protection at edge of slab: Floor fire rating may need to extend to the interior face of the exterior wall.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has adequately analyzed the applicable building codes, specified and detailed a fire stop system to maintain continuity. Some codes may require a rated penetration UL-listed assembly or curtain wall mullion fire stop systems. This could affect curtain wall design and mullion location and spacing.
- o Construction Phase: Periodically inspect for quality of installation.

Xf.2 Blowing Embers: External materials must be selected for resistance to fire from blowing cinders.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has specified materials resistant to combustion from blowing embers.
- o Construction Phase: Specified materials are provided and installed as required to prevent flame.

Xf.3 Smoke Intake: Louvers and other fresh air intakes on the exterior of the building may need to be located away from sources of fire and prevailing wind directions.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has located louvers and intakes to maintain air quality and have detailed surrounding construction to remain free of smoke and fire. CFD modeling may be required to predict airflows and contamination.
- o Construction Phase: Verify submittals and construction conforms to design.

R.1.8 Structural Performance

R.1.8.1 Overall Performance

Xs.1 Framing Openings: Large glazed openings may require special framing in enclosure assemblies.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has coordinated structural requirements and indicated sufficient structural steel or other special framing.
- o Construction Phase: structural system and especially anchorage points are installed in compliance with design.

Xs.2 Cantilevered Loads: Light shelves or other devices may impose difficult cantilever loads.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has coordinated with structural engineer to provide anchor points suitable to support light shelf and Cantilevered loads.

- o Construction Phase: submittals include documentation to verify compliance with indicated loads.

Xs.3 Cantilevered Outer Wall: Heavier outer rainscreen, such as brick veneer, require special detailing to support substantial distance outside of structural frame.

CxA should verify that:

- o Design Phase, the DP has coordinated with structural engineer to provide shelf angles, lintels, or other supplemental structural steel required to support the rainscreen.
- o Construction Phase, verify installed structural supports comply with design.

Xs.4 Increased Dead Load from Green Roof: Green roof structure must support weight of soil and retained water.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer to design roof structure for required dead load.
- o Construction Phase: verify that submitted calculations and shop drawings show compliance with indicated design load.

R.1.8.2 Blast Resistance

Xs.5 Blast Load for Exterior Enclosure: Exterior Enclosure will need to be reinforced to accommodate blast load.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has designed all components of exterior enclosure for appropriate loads as determined to resist anticipated blast load.
- o Construction Phase: Calculations submitted by contractor, subs and suppliers demonstrate compliance with indicated loading. Test anchors, components or entire assemblies for load resistance.

See also: Blast Loads of structure.

Xs.6 Blast-Resistant Fenestration: Windows, curtainwall and other glazed areas will need to be laminated glass in heavy frames and/or in systems designed to allow substantial deflection.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has designed all components of exterior enclosure and attachments for appropriate loads as determined to resist anticipated blast load.
- o Construction Phase: Calculations submitted by contractor, subs and suppliers demonstrate compliance with indicated loading. Test anchors, components or entire assemblies for load resistance.

Xs.7 Standoff Distance: Doors, windows and other openings may be influenced by ability to design site for increased standoff distances.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated standoff distances for required blast load, and where appropriate, increased distance through use of barriers or landscape features.
- o Construction Phase: verify standoff distance is maintained.

Xs.8 **Impact Resistant Walls:** Exterior Enclosure at grade will need to be reinforced to resist impact.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has determined threat to Owner's facility and designed a system capable of resisting that threat.
- o Construction Phase: installed system complies with design and periodically test anchors, components or entire assembly for adequate strength, in addition to air and water penetration.

Xs.9 **Blast Load:** Louvers, air intakes and other penetration of the enclosure for use by the HVAC system will need to be located and/or reinforced to accommodate blast.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated the blast load at each mechanical penetration and reinforced louvers and supporting building framing appropriately.
- o Construction Phase: Verify submittals and construction conforms to design. Spot check for calculations documenting conformance.

R.1.8.3 Seismic Resistance

Xs.10 **Seismic Movement:** Exterior Enclosure will need to accommodate seismic movement. More and larger joints will likely be required.

CxA should verify that:

- o Design Phase, the DP has determined joint width with input from structural engineer and detailed properly.
- o Construction Phase, Inspect that materials are not installed that reduce free movement of seismic joint.

R.1.8.4 Forced Entry Resistance

Xs.11 **Break-in Resistance:** Louvers, air intakes and other penetration of the enclosure for use by the HVAC system will need to be located and/or reinforced to resist break-in.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated the risk of break-in at each mechanical penetration and reinforced appropriately.
- o Construction Phase: Verify submittals and construction conforms to design. Spot check for inclusion of screens or burglar bars where required.

Xs.12 **Surveillance:** Doors, windows and other openings may be influenced by ability to observe outside of building by security personnel.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has discussed surveillance requirements with owner and incorporated requirements into design.
- o Construction Phase: changes to exterior features, especially landscaping, do not block required sightlines.

R.1.8.5 Hurricane/High Wind Loads

Xs.13 Rain Penetration: Louvers and air intakes for HVAC and other systems must be specially designed to resist rain penetration during high winds.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has selected louvers and detailed waterproof plenums behind louvers, fully integrated with the louver frame to control any water entrainment that may occur during a hurricane.
- o Construction Phase: Verify submittals and construction conforms to design. Verify hose or flood test has been passed.

Xs.14 Higher Enclosure Lateral Loads: Roof deck and exterior wall sheathing may need to be designed for slightly higher internal positive loads resulting from potential higher interior pressures, especially in hurricane zones.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer to determine appropriate increase in enclosure loads resulting from openings in enclosure.
- o Construction Phase: enclosure loads are not reduced to code minimums as part of value engineering or substitution. Inspect and test for conformance with design and load criteria.

Xs.15 High Wind Loads: Exterior Enclosure will need to be reinforced to accommodate high wind load.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has determined appropriate wind load for facility, either thru analysis of code and weather data or by wind tunnel analysis, and has traced wind loads from components and sub-assemblies of enclosure system through to the main structure and down to foundation.
- o Construction Phase: installed system complies with design and periodically test anchors, components or entire assembly for adequate strength, in addition to air and water penetration.

Xs.16 Flying Debris: Walls and glazed areas need to resist impact and penetration from flying debris.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated exterior enclosure, landscape features and surrounding environment for either

reduction/elimination of flying debris or has designed enclosure to resist the anticipated size and velocity of the debris.
- o Construction Phase: installed system complies with design and periodically test anchors, components or entire assembly for adequate resistance to penetration.

Xs.17 Impact and Hurricane-Resistant Fenestration: Windows, curtainwall and other glazed areas will need to be laminated glass in heavy frames.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has evaluated exterior enclosure cladding materials, landscape features and surrounding environment for either reduction/elimination of flying debris or has designed enclosure to resist the anticipated size and velocity of the debris, or included protection of fenestration during a storm, i.e. storm shutters.
- o Construction Phase: installed system complies with design, anchorage and periodically test anchors, components or entire assembly for adequate resistance to penetration.

R.1.8.6 Geotechnical Bearing Capacity

Xs.18 Uplift: A enclosure may be beneficial to resist uplift caused by hydrostatic pressure.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has coordinated superstructure design; enclosure design and other building dead load designs with the foundation to minimize requirements for extra dead load added only resist uplift. Waterproofing of the foundation may need to include a mud slab for increased quality of installed waterproofing systems.
- o Construction Phase: verify that systems included in dead load analysis are not changed during value engineering to a lighter weight system.

R.2 Integrate Exterior Enclosure with Other Systems

R.2.1 Daylighting

DL.1 Integration of daylighting strategies: effective daylighting involves the integrated design of the envelope, lighting and interior systems. Improper changes to daylight-related aspects of any one of these systems can partially or completely negate daylight benefits. Therefore the CxA should verify that the following general actions occur, since they are important to obtaining a successful outcome.

During design*,* for daylighted spaces, the ***design team*** should verify that the design drawings and specifications provide proper instructions for all daylight-related features including:

- ***Fenestration:*** location, size, and visible transmittance characteristics of all vertical and horizontal daylight apertures.
- ***Solar and Glare controls:*** the dimensions and characteristics of fixed and operable solar and glare control devices such as light shelves, awnings, vertical or horizontal blinds, external shading projections, shutters, etc.
- ***Electric Lighting controls:*** dimming or stepped controls, either manual or automatic, that reduce or turn off the electric lights within the daylighted spaces in response to daylight availability.
- ***Sensors:*** the number, locations, and characteristics of the sensors that monitor daylight availability.
- ***Interior surface characteristics:*** the minimum reflectances of key interior surfaces, such as ceilings, walls, partitions, desktops, and floors within and near the daylighted spaces.
- ***Partition characteristics:*** the locations, heights, and the translucence, transparency, or opacity characteristics of partitions, especially those parallel to the windows, can strongly impact daylighting.
- ***Visible Transmittance:*** During design, the exterior enclosure designer has specified the minimum glazing visible transmittance, consistent with NFRC or similar rating procedures.

During construction of the exterior enclosure, that the glazing that is installed meets the specified minimum visible transmittance.

DL.2 Impact of Daylighting: Study required to balance effectiveness of daylighting to reduce heat gain from artificial lighting versus increased heat gain/loss resulting from glazing.

CxA should verify that:

- Design Phase, if daylighting is being considered, that the design team conducts such a study.
- Construction Phase…

DL.3 Surface Reflectances: Using light-colored materials and matte finishes will increase lighting and daylighting efficiency through inter-reflections, and will increase visual comfort. Paint and fabric manufactures provide reflectance values. In general, higher interior surface reflectances improve the effectiveness of both daylighting and lighting systems. Appropriate and achievable reflectances can vary by occupancy type; for office environments, reflectance should not be less than 80/50/20 for ceilings, walls, and floors respectively.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has coordinated the reflective values of interior finishes with the daylighting analysis.
- Construction Phase: Verify that the specified surface reflectances have been attained.

DL.4 Double Façades and Daylighting integration: Properly designed double façades become an integral part of the building's daylighting system. Manual or automated shading devices or louvers located within the double façade layers can be controlled to reflect light deeper into the interior of spaces while blocking or mitigating glare. Properly angled louvers can provide views to the outside while blocking potential glare from sky brightness on a sunny day. On overcast days, louvers can be angled to allow greater light penetration from the outside.

If double façade and HVAC integration is employed, then the Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed sufficient studies to determine energy consumption savings and peak load reductions resulting from integration of the double façade with the daylighting and lighting systems and controls, and that the desired visual comfort conditions will be achieved (e.g., illuminance levels, luminance ratio limits within occupant fields of vision, and glare limits).
- Construction Phase: Verify installation and operation of daylighting-related active façade components and commission their controls. Verify that components of façade systems, and related daylighting control systems, required for energy savings are provided, and are properly located and calibrated. Verify owner is trained in how the daylighting aspects of the double façade system perform and relates to the daylighting system.

R.2.2 Interiors

R.2.2.1 Interior Construction Issues

I.1 Mass Exposed to Occupied Spaces: To be effective, mass materials such as concrete and masonry should be exposed to occupied spaces. Thus, finish materials should not interfere with the absorption and re-release of thermal energy. Thermal mass can be used for either passive heating or passive cooling purposes.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has (1) included interior thermal mass in energy models, (2) included that mass in the construction

documents, and (3) included the mass in the diurnal and seasonal analysis of maintenance of thermal comfort conditions within the impacted occupied spaces.
- Construction Phase: Verify that (1) if exposed masonry is specified, that it is not substituted with lighter weight construction or covered by finishes for decorative or cost reasons that block absorption and release of heat, or (2) that insulation type or placement not be changed to adversely affect the masonry thermal performance projected during design.. Verify that thermal comfort conditions are maintained.

I.2 **Usable Floor Space:** Columns outside of enclosure may allow more useable floor space inside the enclosure. The Commissioning Authority should verify the following:
- Design Phase: The Design Team has adjusted net to gross floor area calculations in OPR.
- Construction Phase: Building construction reflects the design.

I-2a **Below-grade Spaces:** Use of occupied below grade space may need to be minimized or eliminated if adequate ventilation and access to daylight or views to outside cannot be provided.

CxA should verify that:
- Design Phase: The Design Team (DT) has considered this issue.
- Construction Phase: Building construction reflects the design.

R.2.2.2 Interior Partitions

I.3 **Interior Pressurization:** Interior partitions may also have to be designed considering mechanical pressurization schemes. The Commissioning Authority should verify the following:
- Design Phase: The Design Team has coordinated mechanical pressurization scheme and has adequately designed and detailed interior partitions to resist loads and passage of air
- Construction Phase: Periodically inspect interior partitions and details of penetrations and edges for air seal, test representative sampling for air leaks.
- Occupancy Phase: Any post-construction interior partition design or re-design is consistent with mechanical pressurization schemes in place.

I.4 **Shaft Pressure:** Interior partitions at shafts may also have to be designed for differential pressures. The Commissioning Authority should verify the following:
- Design Phase: The Design Team has coordinated mechanical pressurization scheme and has adequately designed and detailed interior partitions to resist loads and passage of air.
- Construction Phase: Periodically inspect interior partitions and details of penetrations and edges for air seal, test representative sampling for air leaks.

I.5 **Translucent Furniture Partitions:** In open plan offices with daylighting from vertical fenestration, consider using translucent or transparent partitions for above desk height furniture partitions that are parallel to the fenestration to increase the daylighting penetration into the space.

If non-opaque furniture partitions are considered for daylighting open office spaces, then CXA should verify:

- o During design, that the daylighting design specifies the use of the non-opaque furniture partitions.
- o During installation of the interior furniture system CXA should verify the installation of the specified translucent or transparent partitions in the locations parallel to the vertical fenestration.

I.6 **Lower Furniture Partitions:** In open plan offices consider using furniture partitions of lower height to increase the efficiency of both daylighting and electric lighting efficiency by reducing shadows and light absorption. May conflict with occupant desires for privacy.

For daylighting in open office spaces with furniture partitions CXA should verify:

- o During design, that the exterior enclosure designer and/or electrical engineer/ lighting designer have specified maximum furniture partition heights appropriate to the daylighting design.
- o During installation of the interior furniture system CXA should verify that partitions of the proper height have been installed.

R.2.2.3 Interior Finishes

I.7 **Surface Reflectances:** Using light-colored materials and matte finishes will increase lighting and daylighting efficiency through inter-reflections, and will increase visual comfort. Paint and fabric manufactures provide reflectance values. In general, higher interior surface reflectances improve the effectiveness of both daylighting and lighting systems. Appropriate and achievable reflectances can vary by occupancy type; for office environments, reflectance should not be less than 80/50/20 for ceilings, walls, and floors respectively.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated the reflective values of interior finishes with the daylighting analysis.
- o Construction Phase: Verify that the specified surface reflectances have been attained.

I.8 **Vapor Permeance:** Interior finishes must not block flow of vapor in hot climates and where drying to interior is required.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has performed adequate study, preferably using computer modeling such as WUFI, to determine need for vapor barrier, appropriate location and permeance of other layers in assembly.

- Construction Phase: verify that permeance of interior finishes complies with the design.

R.2.3 Ventilation

R.2.4 HVAC

H.1 Infiltration/Exfiltration: HVAC system may be reduced based on reduced air infiltration/exfiltration. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed adequate energy modeling based on infiltration/exfiltration predicted for enclosure systems planned for project to optimize capacity of mechanical system.
- Construction Phase: quality of the air barrier system is not reduced without addressing mechanical system.
-

H.2 Reduced Peak Load: Enclosure features may reduce heating/cooling peak load resulting in a reduced size of ductwork and mechanical system. In particular, reduced size of air-conditioning equipment could save significant HVAC first costs of construction, offsetting possible increases in exterior enclosure costs that improved energy performance. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed adequate energy modeling based on actual design conditions to optimize Capacity and size of mechanical system.
- Construction Phase: verify that enclosure features are not removed from project without addressing mechanical system.
-

H.3 Reduced Mechanical System: Enclosure features may decrease total energy consumption of building. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed adequate energy modeling based on actual design conditions to minimize energy usage. Energy savings may offset extra cost for enclosure features.
- Construction Phase: verify that enclosure features are not removed from project without addressing increased energy costs.

H.4 Downsizing from Natural Ventilation: In selected climates, owners may elect to eliminate mechanical heating and/or cooling systems, and to accept possible occasional thermal conditions outside the desired comfort range. However, if mechanical heating and cooling is installed, it will still be required when the weather conditions are at extremes, the peak loads will not likely be reduced so systems will not down-size, but overall energy usage should decrease as a result of the use of natural or hybrid ventilation. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated energy payback of natural ventilation based on realistic weather records and predictions of interior comfort.
- o Construction Phase: Verify training of owner regarding conditions to expect based on natural ventilation.

H.5 Below-grade Mechanical Spaces: In the event of high below-grade water tables, mechanical systems that are normally located in below-grade service spaces may need to be relocated because the construction of waterproof foundations can be expensive.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated the full cost of below-grade mechanical systems, and relocated the mechanical equipment to other parts of the building if not economically and functionally practical.
- o Construction Phase: Spaces below the water table that are required are properly waterproofed and tested prior to backfill.

H.6 Double Façades and HVAC integration: Properly designed double façades become an integral part of the building's HVAC system that can perform several functions:

- On sunny exposures on hot days, air heated by the sun within the double façade layers can be exhausted to the outside before it becomes a significant load on the building interior.
- On cold days, heated air within the double facade layers on sunny exposures can be moved to exposures that are not receiving solar heat gain.
- In some cases, the double facades can act as return air plenums, maintaining a more even temperature of the inner glass surface under hot and cold outside extremes.

These and related integration strategies can substantially reduce both peak heating and cooling loads and also save considerable energy.

If double façade and HVAC integration is employed, then the Commissioning Authority should verify the following:

- o Design Phase: The Design Team has performed sufficient studies to determine energy consumption savings and peak load reductions resulting from integration of the double façade with the HVAC system, and that the desired thermal comfort conditions are maintainable.
- o Construction Phase: Verify installation and operation of HVAC related active façade components and commission their controls. Verify that components of façade systems required for energy savings are provided. Verify owner is trained in how the double façade system performs and how it integrates with the HVAC system. Verify maintenance of thermal comfort conditions within occupied spaces over a range of outside conditions.

H.7 Humidity Control: Presence or lack of vapor retarder may affect the size and/or design of mechanical system in order to compensate for humidity loss or drying of damp exterior enclosure systems. Note that oversized mechanical systems can result in inadequate drying of interior air and resulting increases of moisture content of interior materials. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has coordinated capacity of mechanical system, along with ventilation, to adequately control humidity in interior spaces and the ability of wall assemblies to remain dry during life of building. Computerized modeling may be necessary to predict moisture content of exterior assembly.
- Construction Phase: Humidity control features of the mechanical system are installed and operational per design intent.

H.8 Oversized Mechanical Systems: Oversized mechanical systems can result in inadequate removal of moisture from interior air resulting in high relative humidity, increase in moisture content of enclosure materials and mold growth.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has coordinated capacity of mechanical system, along with ventilation, to adequately control humidity in interior spaces and the ability of wall assemblies to remain dry during life of building. Computerized modeling may be necessary to predict moisture content of exterior assembly.
- Construction Phase: Humidity control features of the mechanical system are installed and operational per design intent.

H.9 Services Protection: Mechanical services will need to be redundant and buried to protect from fire.

CxA should verify that:

- Design Phase: The Design Team (DT) has considered this factor. Construction Phase. Building construction reflects the design.

H.10 Control of Interior/Exterior Environments: Most reliable system to provide predictable and continuous control of water, vapor and thermal transfer through exterior enclosure, minimizing load contingencies in mechanical design.

CxA should verify that:

- Design Phase: The Design Team (DT) has considered this factor.
- Construction Phase: Building construction reflects the design.

H.11 Interior Drying: System may need to accommodate load from interior side drying of assembly.

CxA should verify that:

- Design Phase: The Design Team (DT) has considered this factor.
- Construction Phase: Building construction reflects the design.

H.12 Roof Top Equipment: Roof top mechanical equipment may not be suitable.

CxA should verify that:

- o Design Phase: The Design Team (DT) has considered this factor.
- o Construction Phase: Building construction reflects the design.

H.13 Underground Services: Services will need to be routed underground for protection.

CxA should verify that:

- o Design Phase: The Design Team (DT) has considered this factor.
- o Construction Phase: Building construction reflects the design.

R.2.5 Controls / Building Automation

C.1 Sensor Location and Calibration: Daylighting systems may be optimized with automatic controls.

The Commissioning Authority should verify the following:

- o Design Phase: Exterior enclosure designer and/or electrical engineer/ lighting designer have located sensors and provided means to adjust and calibrate.
- o Construction Phase: Spot check submissions of sensor and control system, verify performance of system in a mock-up and verify functional testing. Verify owner's training.

C.2 Building Automation System: Sophisticated Double Façade systems require a complicated sequence of operation in order to optimize integration with building mechanical and electrical systems.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated payback of integrating the mechanical and electrical system with the façade and designed a system to suit.
- o Construction Phase: Spot check submittals for conformance, verify a performance test of a mock-up and final acceptance test of the system under all operational sequences. Verify owners have received appropriate training and manuals.

C.3 Motorized/Automated Operation: For natural ventilation and double facades to function without extensive human interaction, a motorized system, generally electrically powered is required.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has indicated required electrical services to operable vent motors.
- o Construction Phase: Spot check compliance of motors with specifications and periodically verify proper installation.

C.4 Mechanized Operation: Natural ventilation and shading systems may be optimized with automatic controls of their operation.

The Commissioning Authority should verify the following:
- o Design Phase: Exterior enclosure designer and/or electrical engineer/ lighting designer have located motors, sensors and processors and provided means to adjust and calibrate.
- o Construction Phase: Spot check submissions of components verify performance of system in a mock-up and verify final functional testing. Verify owner's training.

C.5 **Natural Ventilation:** This provides less capability to tightly control interior temperature and humidity than mechanical ventilation. This should be factored into the design, construction, and operation.

The CxA should verify that:
- o Design Phase: The Design Team (DT) has considered this factor.
- o Construction Phase: Building construction reflects the design.

R.2.6 Fire Control

F.1 **External Structure:** Structure outside of thermal envelope may require special protection from fire. If a steel structure is to be left exposed, fire rating of exterior wall and fenestration may be required. Windows may need sprinklers on interior and exterior surface.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has adequately analyzed the applicable building codes and included protective measures in design.
- o Construction Phase: active and passive measures are installed in compliance with design, periodically test spray-applied fire protection.

See also: Heat flow control: Structure outside of thermal envelope

F.2 **Fire Protection of Surrounding Site:** Automatic fire sprinkler systems or provisions for a manual method (i.e. hose bibs on roof) may be needed to protect surrounding landscape, exterior walls, and roof from external fires

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has adequately evaluated the threat, minimized the threat through site design and material selection and designed an appropriate system.
- o Construction Phase: Periodically inspect for quality of installation.

F.3 **Smoke/Fire Compartmentalization:** Building spaces, thermal zones, and mechanical systems (especially healthcare occupancies) may need to be compartmentalized with smoke partitions and rated assemblies to reduce spread of fire or smoke.

The Commissioning Authority should verify the following:
- o Design Phase: The Design Team has considered compartmentalization, and has aligned the physical compartmentalization of spaces with the compartmentalization of the mechanical systems.

- o Construction Phase: Verify submittals and construction conforms to design. Partitions are smoke-tight with rated penetrations and fire-resistant caulking materials installed at perimeters and penetrations. Spot check to verify that mech systems do not bridge compartment limits.

F.4 **Active Sprinkler Systems:** Routing of sprinkler piping to protect interior side of enclosures (especially curtain walls) can be difficult to conceal. Systems must be coordinated to remain concealed, especially if heads are required on exterior of building.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has indicated sprinkler routing on drawings and coordinated finishes to conceal piping and heads where desired.
- o Construction Phase: sprinkler system submittals are reviewed for coordination with enclosure.

F.5 **Catastrophic Fire:** Enclosure, Mechanical and Electrical systems may or may not be designed to withstand the catastrophic fire, as defined by Owner. Owner may only want to protect structure from collapse or may want building to remain functional after a fire of some predicted size.

CxA should verify that:

- o Design Phase: The Design Team (DT) has reviewed and documented Owner requirements.
- o Construction Phase: Requirements for resistance to catastrophic fire are maintained.

R.2.7 Building Structural

R.2.7.1 Overall Performance

S.1 **Enclosure Gravity Load:** Structure may need to support heavier imposed loads from enclosure.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer to provide support for gravity and lateral loads of enclosure.
- o Construction Phase: verify that anchors and supports for enclosure are attached to main structure at points indicated in documents.

S.2 **Concrete Structure:** Superstructure may need to be concrete versus steel.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has included interior thermal mass in energy models and included that mass in the construction documents.
- o Construction Phase: exposed concrete structure is not substituted with lighter weight construction or covered by other finishes for decorative or cost reasons.

S.3 Light Weight Enclosure: May be possible to reduce structural system due to lightweight enclosure.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer and engineer has designed superstructure and foundation systems for the anticipated loads rather than a typical skin load.
- o Construction Phase: lightweight enclosure is not changed to a system that is heavier than design loads anticipated by structural engineer.

S.4 Heavy Weight Enclosure: Structural System will need to carry weight of heavy façade.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer and engineer has designed superstructure and foundation systems for the anticipated loads and deflection rather than a typical skin load.
- o Construction Phase: enclosure is not changed to a system that is heavier than design loads anticipated by structural engineer.

S.5 Double Façade Structural Loads: Structural System will need to carry heavier weight of double walls and cantilevered/rotational loads from double façade anchorage may need to be addressed.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer and engineer has designed superstructure and foundation systems for the anticipated loads rather than a typical skin load and has designed attachment points that will adequately support higher gravity and rotational loads resulting from double facade.
- o Construction Phase: structural system and especially anchorage points are installed in compliance with design.

See also: Double Facades and natural ventilation, rain-water control, heat flow control, thermal comfort, acoustic control, daylighting, glare reduction, visual comfort, and integration with lighting and HVAC systems.

S.6 Vibration Isolation: Vibration isolation of structure and substructure may be required. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has adequately analyzed vibration and designed an isolation solution
- o Construction Phase: Isolation installed in compliance with design

S.7 Fire-Resistance: Structural system must be either inherently fire-resistive, i.e. concrete or masonry, or have applied fire-resistive covering. Structural system may need to be heavier steel or concrete to resist long term /extreme fire exposure. Applied fire-resistive materials may need to be highly durable

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has adequately analyzed required fire-resistance and durability, including the possible sources and intensity of fires.
- Construction Phase: Fire-resistive coatings are tested for adhesion, density and thickness. Structural system is not reduced to levels that support only the typical loads

S.8 Exposure to Flame: Structural elements need to be protected from both internal and external flame exposures. Exterior cladding needs to meet code requirements for resistance to heat flux. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has adequately analyzed the possible sources and intensity of fires.

Construction Phase: Adjacent materials are not changed to which would increase risk of fire.

S.9 Progressive Collapse: Structure will need to be designed to prevent progressive collapse. The Commissioning Authority should verify the following:

- Design Phase: The Design Team has analyzed all major structural components for collapse predicted by owner's criteria.
- Construction Phase: Progressive collapse members are not reduced based on supporting typical loads.

S.10 Stand-off Distances: Loads on the structure will be highly influenced by site design and stand-off distances.

CA should verify that:

- Design Phase: The Design Team has considered this factor.
- Construction Phase: The construction reflects the design.

S.11 Blast Loads on Structure: Structure will need to accommodate blast loads, both direct to structure and blast loads transferred from enclosure.

CA should verify that:

- Design Phase: The Design Team has considered this factor.
- Construction Phase: The construction reflects the design.

S.12 High Wind Loads on Structure: Structure will need to accommodate high wind loads, both direct to structure and transferred from enclosure.

CA should verify that:

- Design Phase: The Design Team has considered this factor.
- Construction Phase: The construction reflects the design.

S.13 Exposed Structure to Exterior: Some structural elements including concrete and steel may remain exposed to the weather. Protection should be provided such as epoxy-coated reinforcement, galvanizing, air entrained concrete, etc to offset the impact of exposure. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has reviewed the extent of exposure, and provided means of protection and incorporated sloped surfaces to drain.
- o Construction Phase: Verify that types of measures to protect exposed elements are installed.

S.14 Prevention of Galvanic Action: Metals in contact with each other, or other substrates resulting in corrosion should be reviewed for compatibility, and isolated from each other to prevent galvanic action as required. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has reviewed metals in contact with various substrates and verified compatibility or specified measures to isolate certain metals from incompatible adjacent materials. This includes water run-off from upper areas to materials at lower areas.
- o Construction Phase: Verify that types of measures to protect exposed elements are installed, and incompatible materials do not contact each other.

R.2.7.2 Seismic Resistance

S.15 Seismic Response: Owner may wish to have building structure to be more stiff than required by code to allow the building enclosure to survive a seismic event and still perform. More and larger joints will likely be required.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has analyzed the required performance of the enclosure, and detailed a system that can meet required performance values after the building has experienced a seismic event. The Design Team has determined joint width with input from structural engineer and detailed properly. The Design Team has selected a seismic joint system that has an air and water-resistant inner membrane.
- o Construction Phase: Verify that mock-up is subjected to seismic racking tests followed by appropriate air and water penetration testing to prove compliance with design intent. Inspect that materials are not installed that reduce free movement of seismic joint.

R.2.7.3 Stiffness of Structure

S.16 Structural Movement: Structure may need to be stiffened to reduce movement that would need to be accommodated in air barrier.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated allowable deflection and drift with the structural engineer and accounted for the design movement in joints thru each layer of enclosure.
- o Construction Phase: verify that joints are sized per design and have not been bridged by brittle materials.

S.17 Corrosion Protection: Structural members may need extra corrosion protection if located in concealed construction that may be wet at times.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer to specify adequate corrosion protection for members that may be exposed to moisture.
- o Construction Phase: Periodically inspect for specified protection at wet locations. Test protection for coating thickness or other salient features.

S.18 Structural Stiffness: Structure will be more massive to provide necessary stiffness.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer to include adequate depth of structure and size of members to provide necessary vibration attenuation.
- o Construction Phase: lesser size members, capable of supporting typical loads but not capable to provide necessary stiffness are not substituted.

R.2.7.4 Geotechnical Bearing Capacity

S.19 Hydrostatic Pressure: Hydrostatic pressure will need to be resisted against horizontal force and uplifting force. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer to incorporate hydrostatic pressure identified in the geotechnical report.
- o Construction Phase: verify foundation, waterproofing and drainage system complies with design.

S.20 Uplift: A heavier structure may be beneficial to resist uplift caused by hydrostatic pressure.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated superstructure design; enclosure design and other building dead load designs with the foundation to minimize requirements for extra dead load added only resist uplift. Waterproofing of the foundation may need to include a mud slab for increased quality of installed waterproofing systems.
- o Construction Phase: verify that systems included in dead load analysis are not changed during value engineering to a lighter weight system.

R.2.7.5 Durability of Structure

S.21 **Structural Lifespan:** Building structure is least likely to be able to be repaired /replaced so should be designed for maximum lifespan. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has protected structural system from degradation.
- o Construction Phase: Protection is coordinated with structure.

See also: Durability

R.2.8 Double Façade Integration

See also: Double Facades and natural ventilation, rain-water control, heat flow control, thermal comfort, acoustic control, daylighting, glare reduction, visual comfort, structural loads, and integration with lighting and HVAC systems.

R.2.9 Coordination with Electrical

El.1 **Reduced Electrical System:** Reduce size of main electrical service and distribution resulting from reduced HVAC.

CxA should verify that:

- o Design Phase: The Design Team (DT) has coordinated the system size and required electrical service with mechanical and electrical engineers.
- o Construction Phase: HVAC loads are not increased during construction phase.

El.2 **HVAC versus Lighting:** Savings in electrical service from reduced HVAC may be offset by need for more artificial lighting.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.3 **Below-grade Electrical Spaces:** Electrical systems normally located in below-grade service spaces may need to be relocated.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.4 **Foundation Drains:** Emergency power for pumping of foundation drains may be required.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.5 **Electrical Service:** May reduce size of main electrical service and distribution but may increase if balance of heat gain/loss is not optimized.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.6 Complexity: Electrical system complexities will likely increase to accommodate battery storage of PV generated power. CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.7 Connected Load: Connected load to utility may decrease. CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.8 Noise Attenuation: Generators and other sources of noise may need to be attenuated or remotely located.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.9 Generator: Active systems require generator for emergency power.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.10 Emergency Power: Emergency generators may be required if external power sources are susceptible to damage from fire or blast.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.11 Underground Services: Services will need to be routed underground for protection.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.12 Power Interruption: Emergency generator may be required to maintain power after hurricane.

CxA should verify that:

- o Design Phase: The Design Team has considered this factor.
- o Construction Phase: The construction reflects the design.

El.13 Emergency Generator: Active exterior enclosure systems require generator for emergency power.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has sized the load necessary for the generator and designs a system to the correct capacity.
- o Construction Phase: Verify submittals comply with specs and that generator operates under emergency conditions.

R.2.9.1 Coordination on Drainage

Dr.1 Sub-Drainage: Sub-Drainage and pumping systems may be required. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has coordinated with structural engineer and geotechnical engineer for requirement for sub-drainage and with plumbing engineer and electrical engineer for actual piping/pumping system and emergency power supply.
- o Construction Phase: verify that all required submittals are coordinated among various trades required to provide a functioning sub-drainage system.

Dr.2 Roof Drains: Roof drain sizes may be reduced if peak run-off load is to be controlled. Likewise, the size of the storm water and detention systems may be reduced. The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has verified plumbing engineer has sized roof drains for run-off predicted for actual design versus typical roof run-off. Confirm that overflow drains or scuppers are adequate.
- o Construction Phase: Roof drains, storm drains and detention ponds are sized for design.

R.3 Durability

R.3.1 Extended Life Span

Du.1 Serviceability: Systems and materials must be selected and detailed based on anticipated life span and the ability to repair/replace at life span intervals. The Commissioning Authority should verify the following: The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has evaluated each system and the individual components of that system to allow for either periodic maintenance or replacement over life span, or performance over projected lifespan of building without maintenance.
- o Construction Phase: installation method of system does not alter the ability to repair or replace components.

R.4 Value

R.4.1 Views to Outside

Va.1 Views to Outside: For many types of occupancies, the amount of and quality of views to the outside can strongly impact perceptions of building quality and value, including building sale value and rent ability of spaces. The desire for views to the outside can often be a main driver (along with aesthetics) for office buildings with very large glass areas.

The Commissioning Authority should verify the following:

- Design Phase: The views to the outside and glass areas are consistent with the owner's intent, and the Design Team has performed energy and cost analyses of view and glazing area options.
- Construction Phase: Verify that construction matches design. Periodically verify in field.

R.4.2 User controllability

Va.2 Provide Occupants Control of Glare: Provide occupants control of potential glare from windows or skylights during bright sky or direct sun conditions by providing automatic or manual shades or blinds under direct occupant control. This is especially effective in perimeter spaces near large areas of glazing with reasonably high Effective Aperture (EA), or near skylights allowing direct beam solar rays into the occupied space.

- Design Phase: The Design Team has performed comfort analysis for occupants of space based on glare and taken appropriate measures to provide occupants with operable devices to mitigate glare when sun or sky conditions occur.
- Construction Phase: Glare control devices match design. Periodically verify in field.

R.4.3 Thermal comfort

Va.3 Occupant Asymmetric Radiant Loss: In colder climates, use of large areas of glazing may cause asymmetrical radiant heat loss of occupants adjacent to glass. (I.e. baseboard radiation and/or continuous slot diffusers.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed comfort analysis for occupants of space based on temperature, humidity, air movement and radiant loss and taken appropriate measures to control radiant loss such as higher R-value window systems, air curtains, base radiation/convection, etc.
- Construction Phase: Types of glass, mechanical heating and other systems match design. Periodically verify type of glass in field. Verify that testing and balancing obtains proper operation of mechanical system.

R.4.4 Visual comfort

Va.4 Daylight and User Visual Comfort: Daylighting may have a substantial positive impact on user visual and psychological comfort.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has educated Owner to benefits to productivity and health of occupants during early design phases.

- Construction Phase: Important daylighting features are not reduced.

See also: Value->Visual Comfort, Value->Occupant Control.

Va.5 **Excessive contrast in Visual Field:** Avoid high contrast ratios in the occupants' visual field (e.g., contrast ratios greater than 10) and contrast ratios greater than 3 adjacent to task areas.

The Commissioning Authority should verify the following:

- Design Phase: The Design Team has performed comfort analysis for occupants of space based on glare and taken appropriate measures including (1) interior surface colors and reflectance, (2) positioning of glazed areas, (3) operable shades or blinds on glazed surfaces, and (3) illuminate surfaces around punched openings to reduce high contrast, etc.
- Construction Phase: Verify that features of systems measures installed match the design. Periodically verify type of glass in field. Verify that testing and balancing obtains proper operation of mechanical system.

R.4.5 Energy Savings

En.1 **When External loads predominate.** Energy savings from exterior enclosure changes are most effective on structures with HVAC substantially driven by heat loss/gain loads. Energy savings and/or reductions sizing of especially cooling equipment can often pay for part of all of increases in enclosure construction costs. Not as effective on structures with high internal loads.

CxA should verify that:

- Design Phase: The Design Team (DT) has examined exterior enclosure strategies to reduce loads on HVAC and electric lighting systems.
- Construction Phase. The changes have not eliminated the energy savings identified during design.

En.2 **Structure Outside of Enclosure.** Such structure may act as a large heat-sink, increasing energy use.

If significant amounts of building structure are outside of the enclosure, the CxA should verify that:

- Design Phase: The Design Team (DT) has examined and documented ways to reduce that amount of structure outside the enclosure, or that the adverse energy impacts are negligible.
- Construction Phase. The changes have not eliminated the energy savings obtained by design intent.

En.3 **Reflective Solar Barriers.** These are most effective in hot, sunny climates.

CxA should verify that:

- o Design Phase: The Design Team (DT) has examined exterior enclosure strategies to reduce loads on HVAC and electric lighting systems.
- o Construction Phase. The changes have not eliminated the energy savings identified during design.

En.4 Reduced Peak Loads Likely. An exterior enclosure strategy may reduce peak loads and also may save on overall energy consumption.

CxA should verify that:

- o Design Phase: The Design Team (DT) has examined the energy and constructions cost savings of exterior enclosure strategies that reduce peak loads and energy consumption,
- o Construction Phase. The changes have not eliminated the peak load reductions energy savings identified during design.

En.5 Reduced Peak Loads Unlikely. These will not likely be reduced so systems will not down-size, but overall energy usage should decrease.

CxA should verify that:

- o Design Phase: The Design Team (DT) has examined exterior enclosure strategies to reduce loads on HVAC and electric lighting systems.
- o Construction Phase. The changes have not eliminated the energy savings identified during design.

En.6 Energy Savings from Daylighting. Reducing daylighting may increase energy usage.

CxA should verify that:

- o Design Phase: The Design Team (DT) has examined potential reductions in building visual quality and energy savings from reductions in daylighting.
- o Construction Phase. The changes have not eliminated the positive energy bvenefits of daylighting identified during design.

R.4.6 Productivity

R.4.7 Ease of Maintenance

R.5 Noise and Acoustical

N.1 Attenuation, Sources of Noise: Chillers, air handlers, generators, and other sources of noise may need to be attenuated, contained in the interior of the building or remotely located.

The Commissioning Authority should verify the following:

- o Design Phase: The Design Team has studied placement of major pieces of noisy equipment for best location and included sound attenuators, acoustic isolation and other acoustic provisions required to meet mechanical requirements while maintaining acoustic isolation. .

- o Construction Phase: Periodically check isolation and mechanical system submittals and installation to verify special isolation provisions are installed per design. Field test attenuation at start of construction and again at end if critical.

Annex U: Exterior Enclosure Testing Procedures

Contents of this Annex

Commentary

This annex provides information about three types of testing of building exterior enclosures:

1. Laboratory testing and mock-ups
2. Field testing and mock-ups
3. Testing and Evaluation Using Design Information

This annex focuses on field-testing because such field- testing is an important, but seriously under-used, tool for producing higher quality building exterior envelopes.

Credits

This annex has been developed by Bill Nash, with substantial input from Wagdy Anis, Don Acker, Brad Carpenter, Paul Totten, and other members of the committee.

- Sub-annexes U.1a and U.2a have been provided by Wagdy Anis of Shepley Bulfinch Richardson and Abbott.
- Sub-annex U.2b has been developed by Bill Nash of McCarthy Building Companies, Inc. and Wagdy Anis of Shepley Bulfinch Richardson and Abbott.
- Sub-annexes U.2c, U.2d, and U.2e have been provided by H. Jay Enck of Commissioning and Green Building Services (CxGBS).

- o Sub-annexes U.3a, U.3b, and U.3c have been developed by Bill Nash of McCarthy Building Companies, Inc.

1 Laboratory Testing

Many laboratory tests may be performed on exterior envelope systems, components, assemblies and materials. The following is just a partial listing:

- o Window and door products must be tested and certified by the manufacturer for air leakage in accordance with the National Fenestration Rating Council's (NFRC) test protocols, such as NFRC 400, ASTM E283 or E 330.
- o Garage doors are tested according to ANSI/DASMA 105 to demonstrate code compliance.
- o Reasonable air leakage rates for glazed products and doors are required by codes and standards as well as recommended by organizations such as AAMA.
- o Air barrier materials should be tested and qualified per ASTM E2178 not to exceed 0.004 cfm @ 0.3" w.g. or 1.57 psf (0.02 L/s.m^2 @ 75 Pa)[i]
- o Air barrier assemblies should be pre-qualified in accordance with ASTM E 2357, Method for Determining Air Leakage of Air Barrier Assemblies. The commonly specified target for maximum air leakage of curtain wall assemblies is 0.06 cfm @ 6.24 psf (0.3 L/S.m^2 @ 300 Pa).

Assemblies of opaque walls, curtain walls and windows can be tested in the lab in accordance with:

- o NFRC 400 or ASTM E 283 (air infiltration)
- o ASTM E 331 (water penetration under static pressure)
- o AAMA test procedure 501.1 (water penetration under dynamic pressure)
- o ASTM E 330 (structural adequacy)
- o NFRC 500 or AAMA 1502.7 (condensation resistance factor or CRF)
- o NFRC 100 or AAMA 1503.1 (thermal transmittance)
- o NFRC 200 (solar heat gain coefficient and Visible Light Transmittance)
- o NFRC 300 (solar optical properties of glazing products).

Most curtain-wall systems today are specified as contractor-designed systems to performance criteria established in the specifications. Laboratory mock-ups are an invaluable resource for major curtain wall projects, especially for complex projects with custom detailing. Such laboratory mock-ups help to:

- o Determine the curtain wall provided meets the specified performance criteria.
- o Pre-discover any built-in flaws in the design and execution prior to execution on the building.

An example case study of laboratory mock-up testing is contained in sub-annex Ua1.

2 Field Testing

2.1 Introduction – Why is Field Testing Important?

This section presents a series of questions and answers that emphasize the importance of field testing.

What is the number one issue in field-testing? Safety is the number one issue on all construction sites.

Why do Buildings Leak? Defects are found to be due to three primary root causes – Design, Workmanship and Maintenance. These are root causes of heat, air, moisture and mold (HAMM) issues in a building.

What is "Field Testing" of the building envelope? Air and water testing performed on the exterior wall elements as they are installed.

Why is field-testing Important? The specific level of performance must be delivered per the contract specifications

What are the advantages of field water testing? The main advantage is that the buildings that are constructed do not leak (heat, air, moisture – liquid, moisture vapor).

This helps eliminate latent defects.

What projects should do field water testing? All projects (new and rehab), apartments, condos, labs, healthcare, office and industrial. All retrofit projects that modify the building envelope – (Below grade waterproofing thru the skin including the roof).

What if I have a laboratory test? Does my project require Field Testing?

Yes – All projects require field water testing and documentation

What if I have no budget for field water testing? The project must perform – Field Water Testing to provide assurance that the contract requirements are fulfilled. The amount of field-testing is a variable dependent upon the complexity of the building envelope.

How do you test? Testing is as simple as a water bottle a hose/hose rack/calibrated nozzle or as formal as a third party testing consultant performing testing such as ASTM E1105; or AAMA 501.1, .2, .3 testing.

What features of a building envelope should be field water tested? Wall subassemblies of all trades, including: field mock ups, EIFS, Stucco, Metal Panels, Glass Fiber Reinforcing Concrete, Precast, Concrete Masonry, Louvers, Doors Flashing – End DAMS – Lintels, Roof Curbs, Skylights, penetrations (Roof and Wall), Windows, Parapets, Expansion Joints. Submittals all mock-ups should require the submittal a formal plan with approval and documentation. Field Water Testing should include: Formal Plan Submittals Approval and Documentation.

2.2 Condensation Issues

2.2.1 Introduction

All too often, condensation and its prevention are not given adequate attention during building design and construction. The following material is intended to explain condensation, identify its effects, and discuss how it can be controlled.

2.2.2 Condensation and its terms

Air is composed of many gases. One of these is water in its gaseous form, called water vapor. The amount of water vapor that air can hold is a function of temperature. The temperature of an object at which air coming in contact with that object will change to a liquid is known as the dew-point temperature. This process is called condensation.

2.2.3 Condensation control

Ventilation: One way to control condensation is to exchange the high moisture content air with air having a lower moisture content. This is commonly achieved through ventilation.

Vapor retarders: Another method of controlling moisture condensation is through the use of a vapor retarder. Vapor retarders are used to limit the migration of moisture into the fiberglass insulation and onto the sheathing or structural members. Vapor retarders (often improperly termed vapor barriers) do not totally stop vapor transmission; they do serve to reduce its movement. Because moisture travels from areas of higher vapor pressure to areas of lower vapor pressure reassures the vapor retarder should always be placed at the point of the highest vapor pressure. This usually means on the inside, or warm, side of structure. An exception to this rule is if the building is a cooler or freezer and the design temperature inside the structure must be lower than the outside temperature. Another exception could occur in hot or warm climates where the warm side is the outside. Further, in some mid and mild climates that see both moderate highs and lows, except for a few days a year, a vapor retarder may not be required.

2.2.4 Vapor Retarder Performance

A vapor retarder's effectiveness in controlling moisture movement is measured by its perm rating. This is a shortened form of the term "performance," which is defined as the rate of water vapor transmission through a material in a given amount of time per unit area. In U.S. customary units, a performance of one perm is defined as 1 grain of water vapor transmitted per hour pre square foot per 1.0 inch of mercury vapor pressure difference. The lower the perm rating number, the better the vapor retarder. Materials with perm ratings of 1.0 or greater are not usually classified as vapor retarders.

A vapor retarder is important because condensation can occur in two forms. The first form is visible condensation, which can occur when condensation appears on surfaces that are adjacent to the warm side of materials. One can clearly see this. This type of condensation can occur on window glass panes or aluminum framing.

The second form of condensation is hidden or invisible. It can occur inside materials. Examples: moisture absorbed by dry-wall, plywood, ordinary sheathing materials, and the like. Fiberglass insulation will hold moisture either as water or as water vapor.

Vapor retarders come in a wide variety of materials and perm ratings, but none will stop moisture transmission altogether; as the name implies, they will only help retard it. Careful planning in the original design and evaluation of the building will save the building and the owner many condensation problems.

A grain is the smallest unit in the U.S. and U.K weight measurement system. It is equal to 0.0648 gram; one pound avoirdupois equals 7,000 grains.

2.2.5 Specifying a vapor retarder

Extended service life and maximum energy savings in a building will result from specifying the correct facing for the insulation system. An insulation facing can improve building performance by doing one thing: retarding the penetration of water into the metal structure or into the insulation blankets. As the American Society for Testing and Materials (ASTM) states, “Except for structural errors, about 90% of all building construction problems are associated from water in some way. “The ASTM published these findings in report ASTM E241-77 entitled Increasing Durability of Building Construction Against Water-Induced Damage.

During changes in temperature and humidity, a difference in water vapor pressure exists between the inside and outside of a building. This vapor pressure differences is the driving force causing water vapor diffusion. Water vapor passing through the facing and into the cold side of the insulation can condense and adversely affect insulative properties. A good vapor retarder (facing) will resist this water vapor transfer caused by the vapor pressure difference.

Insulation facings with a Water Vapor Transfer Rating (WFTR) of 0.02 U.S. perms (ASTM E96, procedure A) are excellent vapor retarders. According to ASTM C755, Section of Vapor Barriers for Thermal Insulations, “it is assumed that permeance of an adequate barrier will not exceed 1.0 perms although at present this value may be adequate only for residential construction.”

There are many different types of vapor retarders with varying degrees of permeance ranging from vinyl film to high performance composites of metalized polyester, scrim and polypropylene. Understanding the water vapor retarding properties and strength characteristics of the following facings will enable the designer or specifies to optimize the insulation system to meet the requirements of a specific building project.

2.3 Workmanship

The field installation of interfacing building envelope materials requires a thorough understanding of the specific project plans, details, specifications, codes, standards, workmanship standards, work sequence, shop drawings, mock ups tolerances, material compatibility and documentation.

Field water testing proves that the installation meets the project requirements and that the building envelope is functional.

Field water testing of sub assemblies provides assurance that a full ASTM E-1105+ field test will pass when it is run.

An example of incremental or phased water testing would be the testing of masonry base flashing this can be performed by hose testing of the base flashing (or lintel flashing) laps, end dams, inside and outside corners prior to the laying of brick.

2.4 Material Interfaces

Material interfaces are important because material interfaces the joints between differing materials represent less than 1% of the building envelope area but contribute 90% of the root cause of leakages for both air and water.

Material interfaces are typically sealant joints.

2.5 Useful Field Performance Evaluations and Verifications

The following field performance evaluations and verifications are useful for various building envelope wall systems and/or problems

Infrared Imaging of Buildings envelope: Determining the thermal (conductive) performance of roof and wall assemblies. ASTM C1060-90.

Infrared Imaging with Building Pressure Manipulation: Determining the air leakage sites in roof and wall assemblies. ASTM-779-99 method for using fan pressurization equipment to manipulate building pressures.

Smoke Tracer Testing with Building Pressure Manipulation: Determining the air leakage sites in roof and wall assemblies utilizing theatrical fog with and without building pressure manipulation. (ASTM)

Infrared Imaging and Visual Observations to Locate Moisture Infiltration/Leakage into the Thermal Envelope: Under certain defined conditions, IR Thermography, conducted indoors or outdoors with a uniformly heated interiors space, has proven useful in locating currently damp wall assemblies that would be otherwise hard to find. Visual observations for indications/stains/rust for past water damage can also be useful. (ASTM-C 1060-90)

Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, Curtain Walls, and Wall Assemblies: Determining the actual conditions for water leakage, and utilizing intrusive disassembly to locate actual water leakage sites have proven invaluable for problem solving in existing structures. (ASTM-E-1105-00)

Field Determination of Exhaust Impacts on Air Intakes or Impact of Sewer Gas Leakage: Determining the observed airflow pattern of local exhausts or local point sources on air intakes under real life weather conditions. We typically utilize a tracer smoke (theatrical fog) for this evaluation. This method has also worked well for determining sanitary sewer gas vent (odor) re-entrainment or internal leakage sites.

Concrete Floor Moisture Emission Testing: Determining the concrete floor moisture emission rate is a common need in existing structures since the advent of water based floor adhesives. There are draft ASTM testing techniques and other standardized testing methods for this determination. (ASTM F 2170; ASTM F 1869-03)

Building Envelope Pressure Monitoring: In some buildings, it is important to know the actual peak and long-term average pressures that the HVAC system imposes on the building envelope during normal operation, (summer, winter, swing season) versus what may have been intended or designed.

2.6 Field Testing of Installed Subassemblies and Assemblies of the Building Envelope

2.6.1 Field Testing Specifications

The level of field testing on exterior wall systems should be defined by the design professional (Architect/Engineer) in the project contract documents. A field testing scope should be defined which includes locations, testing pressures and types of assemblies (Refer to ASTM E 2099 “Standard Practices of the Specification and Evaluation of Pre-Construction Laboratory Mockups or Exterior Wall Systems.

Laboratory tests are not applicable for field tests. Lab tests include structural, thermal, missile or windborne debris impact, and seismic and wind induced inter story drift testing. Structural testing has been performed in the field when the performance of a specific system must be confirmed.

The primary purpose of the field testing of installed wall systems is to assess the impact field conditions have on the wall system performance and for quality control of the installed wall, or to assess the performance of unique portions of the wall system that were not included in the project laboratory mockup.

Field testing is used for observing water penetration using test methods: ASTM E 514, ASTM E1105, AAMA 501.2, AAMA 502-02, AAMA 503-03 and to a lesser extent air leakage testing. Field testing of a mock up of a curtain wall system for water penetration and air leakage rate should be performed after a preconstruction laboratory mock up test has been performed on a wall system. The purpose of the field testing is to verify the performance of the envelope system installed on the building. The field testing provides an assessment of the wall system as it is installed on the building (workmanship) incorporating the actual construction constraints which often times are not present in the laboratory constructed mock up, such as at the attachments of the envelope system to the building's structural elements and the actual differing materials comprising the envelope.

Field testing is used to assess the installed workmanship of the wall assemblies. Laboratory testing of windows is a requirement of AAMA to qualify a product for sale in the market place as meeting a certain performance criteria of design. Professionals rely on this qualification testing information to select an appropriate window grade from Residential, Light Commercial, Commercial, Heavy Commercial, and Architectural. The laboratory testing requires sample windows to undergo a series of tests including: structural, air leakage, water penetration, seismic, impact resistance. This testing is performed with the windows installed into a laboratory constructed test chamber frame that does not reflect the varying frame conditions into which windows are installed in the field. Experience has shown that the varying frame conditions can have a detrimental affect on the performance of field-installed windows from the level of performance determined in the laboratory tests.

The majority of the field-testing performed on installed windows is water penetration testing and to a lesser extent air infiltration testing. The field-testing performed on installed windows include both ASTM and AAMA:

- ASTM E 514 "Test Method for Water Penetration and Leakage through Masonry."
- ASTM E 783 "Standard Test Method for Field Measurement of Air Leakage through installed Exterior Windows and Doors"
- ASTM 1105 "Standard 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"
- AAMA 501.2-03 "Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems"
- AAMA 502-02 – Voluntary Specification for Field Testing of Windows and Sliding Glass Doors
- AAMA 503-03 – Voluntary Specification for Field Testing of Storefront, Curtain Walls, and Sloped Glazing Systems

Field Water Testing of installed storefronts, curtain walls, and sloped glazing systems is for quality assurance. AAMA 503 is the correct test method for field testing of storefronts, curtain walls, and slope glazing for air leakage resistance and water penetration resistance performance."

ASCE 7-02 (ASCE 7-02 American Society of Civil Engineers Standard – Minimum Design Loads for Buildings and Other Structures) provides the guidance for the geographic location and the minimum wind speed for which a structure and its building envelope are required to be designed.

2.6.2 Field Testing of Operable Windows and Doors

AAMA 501.2 is not appropriate for the testing of operable components such as operable windows and doors; AAMA 502 is the proper test method for field air leakage resistance and water penetration resistance testing of operable windows and doors.

This field check procedure (ASTM 501.2) is intended to evaluate those joints, gaskets and sealant details in the glazing that are designed to remain permanently closed in water tight position.

- AAMA 502 “Voluntary Specification for Field Testing of Windows and Sliding Glass Doors”
- AAMA 503 “Specification for Field Testing of Metal Storefronts, Curtain Walls, and Sloped Glazing Systems”

The AAMA tests specifications refer to the ASTM test methodologies to specify the required direction for carrying out the testing, however, the AAMA test methods provide parameters for scope.

2.6.3 Field Testing of the Building Envelope – Hose Test

A Hose Test can apply a water spray over a large area or a concentrated water stream to a small area. Unless the nozzle is calibrated, it is difficult to regulate pressure and volume. The Hose Test requires a minimum of two people – one to direct the water and the other to check for intrusion to the interior during water application. This test can identify areas and sometimes individual points of water entry by alternately masking off assemblies and sealant joints and testing.

2.6.4 Moisture Meter

A Moisture Meter can provide a ‘map’ of the locations of moisture in the wall assembly. Moisture Meters are designed and calibrated for the specific substrate such as wood, concrete, drywall. Otherwise the use of a Moisture Meter does not accurately measure the existing moisture. Non calibrated moisture meters can provide a map of the existing conditions comparatively wet, moist or dry areas.

Field water testing can be performed using any or all of the following, where the test methods range from the simple to the complex:

- Water Bottle
- Hose – Garden Hose with nozzle
- Calibrated Nozzle – Monarch Type B-25
- Site Fabricated Hose Rack – PVC Pipe with 0.25” holes drilled
- AAMA – Field Testing
- ASTM – Standard Test Methods

- o Mother Nature – Weather, Storms – During or after rains site staff should walk buildings to observe leakage areas during building envelope installation.

2.6.5 Field Mock Up Testing

Field testing of a mockup of a wall system for water penetration and air leakage rate may be performed without prior job specific laboratory testing. Field testing without job specific laboratory testing is generally performed on projects for which the wall system is a manufacturers standard wall system or on projects which are small in scale and do not warrant a budget for project specific laboratory testing. Additionally, field testing of portions of a custom curtain wall system for which there are unique design conditions that have not been incorporated into a laboratory mockup specimen.

On custom curtain wall systems there are singularly unique design features/areas for which it would be impracticable to perform laboratory testing on each of these specific project conditions, due to complexity and costs however, field testing of these areas is desirable to provide a level of assurance against air and water penetration. Note: (Quality Assurance Field Water Testing should be performed on all custom curtain wall.

2.6.6 Testing of Mockup Wall

Because the building envelope wall subassemblies (wall, door, and window systems) must be sequentially and completely constructed prior the envelope could be tested for water-tightness, a mockup wall is constructed. The wall, door, and window sections then set the standard of quality for the rest of the building envelope work. The installation of each component of the wall assembly must be inspected for compliance with the construction documents, manufacturer's installation instructions, and construction checklists develop by the Construction Manager, General Contractor, Building Envelope subcontractors and the building envelope peer reviewer.

Each wall component is photographed as it is installed for future reference. The photographic documentation is critical to the success of the mockup of the building envelope for setting the standard of quality for the project. The construction sequence of the building envelope components covers up the next layer in the sequence of the skin/ envelope installation. For example, the flashing, as well as other components, covers the membrane waterproofing, the stone or masonry covers the flashing and its terminations, laps, end dams, inside corners, outside corners. Without photographs, there would be no documentation of the successful installation.

The Building Envelope Commissioning Process reviews submittals and substitutions to insure that the moisture control (both water and vapor) and air barrier criteria are functionally installed throughout the construction process, and to finalize the functional f test procedures for moisture intrusion field testing.

2.6.7 Testing of Mockup Wall Sliding Glass Door Assemblies

Sliding glass door assemblies should be identified at the beginning of a project as an area of concern for water intrusion; therefore, a functional test procedure should be developed by the BECP based on the following standards:

- Test Method A: AAMA 502-2; Voluntary Specification for Field Testing of Windows and Sliding Glass Doors

- Test Method B: ASTM 1105; Standard 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 (ASTM 1105 is a reference standard within AAMA 502-02 for water-spray testing field procedures and test apparatus).

The windows and doors specified in the contract documents should meet the performance criteria outlined in the project specifications. For field testing, these tests involve e placing of the door or window assembly under a negative pressure from the inside, with water sprayed on the outside at a specified rate and in a specified pattern.

One testing requirement that can become critical is how much negative pressure the wall assembly should be placed under for the testing. As an example, the project specifications state the door is to be rated for 10 pounds per square foot (psf) in factory testing, but did not state the field testing requirement. The ASTM test standard suggests that 2/3 of the factory standard can be used for field testing, but this is a not a rigorous requirement. Based on experience, one can make a case that testing at 10 psf would provide a margin of safety that would allow door system performance to degrade slightly over time while still maintaining water-tightness. The manufacturer and the subcontractor preferred the tests be conducted at the 2/3 suggestion or 6.7 psf. The mockup doors were tested at 10 psf to assure installation quality and the remainder of the doors were tested 6.7 psf.

Based on the changes put in place by the manufacturer and the observations made during the installation of the mockup wall assemblies, the original construction phase checklist must be refined. Each subcontractor should be required to inspect their work using the checklist and sign off that it had been completed properly. Follow up with random inspections to ensure the contractors were doing the installation work properly. After random water spray testing of an additional wall sections.

2.6.8 Air Infiltration Testing

To determine if the air barrier functions of the envelope are constructed properly, air infiltration testing is conducted on a random sample of rooms using a blower door assembly following the protocols detailed in ASTM Standard E799-87, “Test Method for Determining Air Leakage by Fan Pressurization.” The blower door testing and subsequent relative pressure testing are preformed to assure the envelope construction is tight, and that the HVAC systems is the building have no trouble meeting the positive pressurization design developed for the HVAC system.

2.6.9 Investigating Water Leaks

There are several tests available that are used as a part of a water leakage diagnostic program one of these diagnostic tests is the ASTM 1105, “Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Difference.” In this test a spray grid calibrated spray rack with multiple spray nozzles positioned outside the wall applies a uniform spray of water against the surface of the wall. This test was developed for use with metal and glass curtain walls to identify leaks when the wall was subjected concurrently to air pressure differential. In masonry walls, however, it is often not practical or essential to provide the pressure differential. The exterior surface of the wall is selectively masked to isolate potential sources of leaks.

The water testing should be performed by beginning at the bottom of the wall. The first wall areas to be tested should also be those least likely to contribute to the leakage. If the most likely wall leakage areas are tested first, it will often be difficult to determine if there are other contributors to the problem. Interior openings in the wall assembly should be made to identify where leaks are observed. After water testing is complete- that is the testing has recreated the leakages to the interior space, openings/removals should be made on the exterior of the wall to identify as-built conditions that contributed to the specific problem. Multiple root causes may be contributory to envelope leakage.

2.6.10 Investigating Leakage in a Masonry Wall System

Water leakage test methods include wall drainage system testing and nozzle testing of the wall assembly. Wall drainage tests introduce small amounts of water directly into the masonry drainage cavity at points spaced across the length of the wall. The water, which runs down the back of the exterior veneer, tests the effectiveness of the drainage cavity and the base flashing system. By spacing the observational entry points close together, starting low and loving high on the wall, it is possible to observe that the cavity is draining freely and that water is not bridging across to the backup wall. When water reaches the base of the wall, the flashing and weep system can be evaluated. The test is a pass-fail test. If leakage occurs, openings (removal of the masonry units is required) should be made at leak locations to determine/observe the dysfunctional wall assemblies/subassemblies base flashing, end dams, inside corners, outside corners, lintels, expansion joints, windows, doors, louvers, wall penetration’s are sprayed incrementally from bottom to top while concurrently monitoring for leakage to the interior.

A calibrated hose nozzle can also be used to test sealant joints in masonry walls. The calibrated nozzle is assembled in accordance with AAMA 501.2, “field check of metal curtain walls for water leakage.” Designed for curtain walls, the calibrated nozzle procedure also tests sealant joints in masonry walls or at interfaces with windows or other envelope components of the wall such as metal panels, stucco, EIFS, precast concrete, Concrete Glass Fiber Reinforced Concrete (GFRC), metal shingles, curtain wall, louvers, doors, wall penetrations.

2.6.11 Investigating Leakage of a Roof System

Using a hose + garden nozzle spray water starting low on the roof penetrations – such as roof curbs, duct and piping penetrations, parapets, roof flashings, parapet metal caps.

The structural engineer/DOR must be consulted and formal permission obtained prior to any flood testing of the roof.

3 Evaluations By the Architect/Engineer Using Design Information

This sub-annex contains guidance for architects, analysts, and designers of the types of exterior enclosure system evaluations that should be performed.

3.1 Office/paper calculation reviews and/or tools

In new construction situations, there are several types of building envelope office/paper calculations and field diagnostic evaluations that can be performed. These analyses can be done after the fact to assist in the determination of failure modes or performance, or during design review (before construction) to predict the expected performance of the building – both wall and roof assemblies.

3.2 Dew Point/Vapor Pressure Review

Predicting the vapor pressure relationships and location of dew point occurrences in wall, roof, or floor assemblies in occupied facilities, with significant indoor winter humidity, or significant outdoor summer humidity. Calculation tools include calculations found in American Society of Heating Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) Fundamentals publications.

3.2.1 Exterior Drainage Plane/Wind Barrier Review

Design drawing review for the continuity and constructability of exterior drainage planes intended to keep wind driven rain (liquid water) out of the thermal envelope, and reduce the impact of liquid water/wind (infiltration) on the thermal envelope layers.

3.2.2 Interior Air Barrier/Vapor Barrier Review

Design drawing review for the continuity and constructabi8lity of interior air/vapor barriers designed to keep interior moisture out of the thermal envelope, and reduce the impact of interior moisture/air leakage (exfiltration) on the thermal envelope layers.

3.2.3 Exhaust Re-entrainment Review (Micro Climate Analysis)

Design drawing review and calculations, if needed, for predicting the expected impact of local point source emission sites, and exhaust locations on air intake locations (including operable windows and doors). Calculation Tools include calculations methods found in ASHRAE 2005 Fundamentals – Chapter 16.

3.2.4 Thermal Performance Continuity Review

Design drawing review for predicting the expected continuity and thermal performance of a wall, roof, and below grade assemblies are based on actual conveyed construction details. This review also includes review of thermal breaks and vapor barriers in all earth contact areas. This is especially important with building envelopes that are expected to be high performance, and which include metal (conductive) structural components. Calculation tools include calculations found in ASHRAE 2005 Fundamentals – Chapters 29, 30)

3.2.5 Thermal Performance Peak/Peak Occupancy Air Conditioning Impact Review

Design drawing review for predicting the expected impact of planned or sometimes unplanned occupancy periods, combined with low angle solar gain and glass (fenestration) design, on HVAC peak room cooling loads at maximum winter, low sun impact angles. Calculation Tools include calculations found ASHRAE 2005 Fundamentals Publication – Chapter 29, 30)

3.2.6 Building Envelope Pressure Review:

Design drawing review for the predicting the expected overall long-term average building pressure relationship between the inside and outside of the building envelope under summer, swing season, and winter conditions.

3.2.7 Building Envelope Air Leakage Review:

Design drawing review for predicting the expected building air leakage rate and air leakage sites due to expected stack effect or planned pressure levels. (ASHRAE 2005 Fundamentals – Chapter 27)

3.2.8 Roof Ice Dam Review:

Design drawing review for predicting the likely occurrence of roof snow melts from interior exfiltration or winder solar roof gain and subsequent ice damming in vented for un-vented roof assemblies. This is most applicable on roofs where microclimates and building roof designs are expected to significantly impact snow accumulation on a given Southern or Northern roof exposure.

4 Credits

This annex document has included materials from the following building envelope sources relative to the field-testing materials.

1. **Condensation Control** – Butler Buildings, website is MK:MSITStore:C\Program%20files\BUTLER\ADVANTAGE\Advant

2. **Tricky Brick**, Norbert Krogstad, Wiss Janney Elstner Associates, Building Renovation magazine, Spring 1995, pages 43, 44, 45, 46

3. **Retro-Commissioning & Commissioning Building Envelope Systems to Reduce Health Risks & Improve IAQ- What we have learned to date" – Turner Building Science**, LLC, William Turner, Steven Caulfield, Brian Decker, Frederick McKnight, David Hart, Loren Belida, National Conference on Building Commissioning , May 4-6 2005

4. **Commissioning the Building Envelope: Surviving Hurricanes Charley, Frances, and Jeanne---** R. Bruce Parzych, US Army Community & Family Support Center, David MacPhaul, CH2MHILL, National Conference on Building Commissioning, May 4-6, 2005

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[i] As qualified by the Air Barrier Association of America, the ASHRAE HOF, ASHRAE's Advanced Office Building Design Guidelines, the New Buildings Institute's Benchmark for Advanced Buildings, the Commonwealth of Massachusetts Building Code, and The Model National Building Code of Canada and AIA Masterspec.

Annex U.1a:
Laboratory Testing of Assemblies and Mock-ups

This sub-annex contains a case study example of laboratory testing of a curtain wall assemblies and mock-ups. Another sub-annex U.2a contains a parallel case study of the field-testing of assemblies on the actual building for the same project.

Project: Children's Hospital of Wisconsin Administration Building

Case Study By Wagdy Anis AIA, LEED-AP, Member ASHRAE
Shepley Bulfinch Richardson and Abbott
Architecture - Planning - Interior Design
http://www.sbra.com

U.1a.1 Laboratory Pre-qualification Testing for Air Leakage:

Window and door products must be tested and certified by the manufacturer for air leakage in accordance with the National Fenestration Rating Council's (NFRC) test protocols, such as NFRC 400, ASTM E283 or E 330; Garage doors are tested according to ANSI/DASMA 105 to demonstrate code compliance. Reasonable air leakage rates for glazed products and doors are required by codes and standards as well as recommended by organizations such as AAMA. Air barrier materials should be tested and qualified per ASTM E2178 not to exceed 0.004 cfm @ 0.3" w.g. or 1.57 psf (0.02 L/s.m^2 @ 75 Pa)[i]; air barrier assemblies should be pre-qualified in accordance with ASTM E 2357, Method for Determining Air Leakage of Air Barrier Assemblies. The commonly specified target for maximum air leakage of curtain wall assemblies is 0.06 cfm @ 6.24 psf (0.3 L/S.m^2 @ 300 Pa).

Assemblies of opaque walls, curtain walls and windows can be tested in the lab in accordance with NFRC 400 or ASTM E 283 (air infiltration), ASTM E 331 (water penetration under static pressure), AAMA test procedure 501.1 (water penetration under dynamic pressure) ASTM E 330 (structural adequacy); NFRC 500 or AAMA 1502.7 (condensation resistance factor or CRF), NFRC 100 or AAMA 1503.1 (thermal transmittance), NFRC 200 (solar heat gain coefficient and Visible Light Transmittance), NFRC 300 (solar optical properties of glazing products).

U.1a.2 Project specific Lab Testing of Mock-ups:

Most curtain-wall systems today are specified as contractor-designed systems to performance criteria established in the specifications. For major curtain wall projects, especially for more complex projects with custom detailing, lab mock-ups are an invaluable resource to a) determine the curtain wall provided meets the specified performance criteria and 2) to pre discover built-in flaws in the design and execution prior to execution on the building.

Figure 1. Lab mockup during ASTM E283 air infiltration test

For major laboratory testing of exterior walls, procedures are written up in the specifications for the tests needed and the sequence of testing. The mock up testing is usually bid between one of the few large qualified testing laboratories.

Chamber and structural supports are normally provided behind the wall, with intermediate platforms and stairs that allow for close inspection of the interior. The mock-up is built in the lab by the same companies that will build the building. The cost for a major mock-up is upward of $200,000 (2006) including shop drawings, building and testing, and must be justifiable for the project size and complexity; the return is usually the knowledge of building a trouble-free building with schedule benefits to make up for the advanced scheduling needed for a major mock-up. Typical procedures for testing can be as follows:

U.1a.3 Tests

Normally, the glazing or curtain wall subcontractor does not get the mock-up(s) "pretested" without prior permission from the Architect and Contractor. If permission is granted, "pretesting" is only performed in the presence of the Architect and/or his/her authorized representatives. The testing laboratory is responsible for conducting and reporting the tests, referencing the approved shop drawings, and specifically notes any deviations. The testing laboratory submits its report directly to the Architect and General Contractor. Necessary corrections to the work are performed in the presence of the Architect and/or his/her authorized representatives or consultant. All tests are witnessed by the Architect and/or his authorized representatives.

Order of tests performed:

1. Preload.
2. Air infiltration static method. (Including chamber calibration.)
3. Water penetration static method.
4. Water penetration dynamic method. (Including engine calibration.)

5. Uniform and concentrated load deflection test at design wind load and window washing scaffold tie-back anchor at design conditions.
6. Interstory differential movement, vertical and horizontal displacement test --- six (6) cycles. Test method is usually developed in conjunction with the testing laboratory, Architect and Project Structural Engineer to ensure test is a reasonable replica of what can be anticipated on the structure. Test specimen is then left in maximum open horizontal joint condition at conclusion of testing for the continuation of test.
7. Condensation resistance AAMA 1503.2 with each of both test conditions maintained for 24 hours after equilibrium has been maintained.
8. Thermal cycle. (Six (6) cycles).
9. Structural test at 1.5 times design load. Depending upon the design of the system.
10. Interstory differential horizontal/seismic test to verify connection and panel joint design satisfies requirements of ASCE 7 Section 9.5.2.2.4.3, six (6) cycles. At conclusion of test, wall shall be structurally intact and sound.
11. In event structural silicone is employed to provide structural bond, apply 30 PSF negative load for one minute and inspect work for loss of silicone adhesive bond under load.
12. Perform supplemental test as directed by removing sealant at locations, as determined by the architect, and retesting for water penetration to verify sufficiency of internal drainage systems.

Figure 2 Dynamic Water test

Figure 3. Strain gauges for measuring inter-story drift

Figure 4 Installing hydraulic jacks to simulate inter-story drift.

Upon completion of testing, contractor provides "as built" mock-up drawings showing any modifications or additions required to meet the performance requirements and submit them for review.

In the event that failures after formal testing commence necessitate retesting, (which is not unusual) the contractor usually pays the additional laboratory fees and any fees and expenses incurred by the owner, architect and their authorized representatives or consultants as a result of retesting.

Since curtain walls are often specified as contractor-designed systems to meet the performance requirements of the specifications, the contractor is usually liable for any failure to meet test requirements without adjustment to the contract sum or the contract schedule.

Mock-up materials and assemblies, as tested and approved, govern materials and assemblies furnished for field erection. Contractor goes through a process of revising all project shop drawings to conform to the accepted mock-ups and resubmits for acceptance.

Mock-up acceptance must be properly scheduled to avoid construction delays.

Mock-up materials are normally not installed as part of the building.

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[i] As qualified by the Air Barrier Association of America, the ASHRAE HOF, ASHRAE's Advanced Office Building Design Guidelines, the New Buildings Institute's Benchmark for Advanced Buildings, the Commonwealth of Massachusetts Building Code, and The Model National Building Code of Canada and AIA Masterspec.

Annex U.2a:
Field Testing Case Study Example

This sub-annex contains a case study example of field-testing of curtain wall assemblies and mock-ups. Another sub-annex U.1a contains a parallel case study of the laboratory testing of a mock-up and assemblies for the same project.

Project: Children's Hospital of Wisconsin Administration Building

Case Study By Wagdy Anis AIA, LEED-AP, Member ASHRAE
Shepley Bulfinch Richardson and Abbott
Architecture - Planning - Interior Design
http://www.sbra.com

U.1a.1 Field Quantitative Testing

ASTM E 1186 contains several useful qualitative tests for use in chasing down air leaks and other building defects. Infrared scanning with pressurization / depressurization, is useful in determining air leaks in the winter or summer. In the winter, leaking warm air heats up the enclosure and shows up as a bright spot in the picture (this can also be caused by a thermal bridge, that can be identified from the design details, or insulation inadequacies during construction).

Figure 5
Note heat leakage at the roof-wall intersection, around windows and at the corner.

The reverse happens in the summer with air conditioning indoors, the dark spots are spots cooled by exiting cool air, or other enclosure problems. There are several other tests within E1186 that are rarely used, but two are worthy of note. Chamber pressurization/depressurization in conjunction with smoke tracers is a useful test to determine the location of air leaks in connections between building components such as windows and skylights with their adjacent constructions.

Figure 6

A chamber is created using polyethylene and a simple wood frame (Figure 2), a smoke device is released, or generated using theatrical foggers, while air from a fan depressurizes or pressurizes depending on the configuration. Chamber depressurization using detection liquids utilizes a device nicknamed the “bubble gun” (Figure 3). A bubble solution is spread on the suspected penetration or joint, such as a brick tie fastened to a wall. The plastic dome of the device is placed over the area and depressurized to 500 Pa (2.0” w.g.). Bubbles form if there is an air leak.

Figure 7

Figure 8

U.1a.2 Field Quantitative testing:

The bond of the air barrier to its substrate is important because of the requirement of the membrane to transfer the design wind negative loads to the substrate. Manufacturers of most air barrier products that are either peel-and-stick or liquid-applied publish data on quality of adhesion to substrates. ASTM D 4541 can be followed to do testing using a pull-meter. A disc is epoxied to the material to be tested, and the material is cut around the disc (Figure 5). Tightening the device pulls the material to failure (Figure 6), and the test pressure is recorded and compared to the manufacturer's specifications.   A 12 psi minimum bond should be satisfactory for long-term durability. Note that patching of the test area will be necessary.

Figure 9

Figure 10 ASTM D 4541 adhesion pull testing

The adhesion quality of air barrier membranes can be affected by the wetness of the substrate before application or by low application temperatures.

ASTM E783 is a test for air infiltration of wall or window assemblies. ASTM E1105 is a spray rack water infiltration testing of wall or window assemblies on site, using the same pressurization / depressurization equipment as E783 and is usually run at the same time as E783.

Error! 

Figure 11 ASTM E 783 test with exterior chamber,
testing a window and its perimeter window-to-wall joint

Figures 12 and 13: Field-testing of water penetration to ASTM E 1105
with spray rack.

Figure 14 Hose spray testing at 15 psi, AAMA 501.2 test protocol.
This is a simple test that discovers problems quickly

Figures 15 through 17 for roofing, waterproofing and vegetated roofs, Electric Field Vector Mapping is an extremely useful and accurate tool for pin-pointing leaks.

U.1a.3 Whole building testing:

Testing whole commercial buildings is usually done for research in the US, although it is more commonplace in Canada, and has become a requirement for building acceptance in England and Wales since 2002. It is likely that as the importance of air tightness of the building enclosure becomes more appreciated or regulated, that whole building testing will become more prevalent in North America. The cost of testing a commercial building can vary from $1000 to $15,000 depending on complexity and size.

Tests include:

1. Whole building, floors, or suites, ASTM E 779, Determining Air tightness of a Building's Air Leakage Rate by Single Zone Air Pressurization.
2. CAN/CGSB 1986 Standard 149.10, Determination of the Air tightness of Building Enclosures by the Fan Depressurization Method.
3. CAN/CGSB 1996 Standard 149.15 Determination of the Overall Enclosure Air tightness of Office Buildings by the Fan Depressurization Method Using the Building's Air Handling System.

Figure 18

Trailer-mounted fans (with very large blower doors) for testing large buildings, delivering up to 55,000 cfm @ 75 Pa or larger are available from a US source[i]; several of these may be required to test a large, leaky, building, although inaccuracies are introduced with the use of multiple fans. In testing a whole building, all the "intentional holes" such as ventilation air intakes, exhaust fan outlets and louvers, elevator shaft smoke exhaust, flues, etc. have to be sealed, usually with polyethylene and tape. Low wind conditions, lower than 8.5 mph (14 kph) and only a small temperature differential between indoor and out (outdoor temperature between 40^0F and 95^0F (5^0C and 35^0C)) helps reduce the influence of wind and stack effects. Interior doors need to be open so that the building is turned into a single zone. The volume of air being moved is recorded at the pressure differential; this is done for several different pressures in steps of 12.5 Pa to 75 Pa. If the building is too large to test with a single fan, multiple fans can be used, or the building's air handlers can be used instead; the fans need to be evaluated for cfm output; the test can then proceed and the fans progressively turned on to pressurize the building with pressure measurements taken at each step.

The flow coefficient C and the flow exponent n are evaluated using the power law equation:

$$Q75 = C\,(\Delta P)^n$$

Where Q75 is the quantity of air leakage (cfm (L/s)) at 0.3" (75 Pa), C is the flow coefficient (c = flow coefficient, cfm/(in. of water)n (L/s/(Pa) n, ΔP is the pressure differential between indoors and outdoors (in. water, (Pa)), n = pressure exponent, dimensionless.

The normalized air leakage rate is then calculated using:

$$NLR_{75} = Q_{75}/S$$

Where NLR_{75} is the Normalized Air Leakage Rate of the Building Enclosure cfm/ ft2 at 0.3" w.g. (L/s.m2 @ 75 Pa, and S is the area of the enclosure including below-grade components and slab-on-grade

Commissioning the air barrier system is important in the design and construction of buildings that are sustainable, healthful, durable, and energy efficient. For high-security buildings, and buildings that have precise controlled environments, unless their building enclosure is designed and constructed as tightly as possible, and the air barrier system commissioned, it would be impossible to pressurize the building adequately to reduce the likelihood of infiltration, thereby potentially compromising the interior environment to chemical, biological or radiological agents[ii], nor would it be possible to precisely control the interior environment. An adequate budget needs to be assigned early on in the project process to fund the commissioning activities needed to ensure a successful outcome that meets the owner's project expectations.

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[i] Infiltec G 54 fan shown.
[ii] Building Ventilation and Pressurization as a security tool, Persily, A. ASHRAE Journal September 2004.

Annex U.2b:
Recommended Practice for the Incremental Inspection and Field Air and Water Testing of Exterior Enclosure Elements

U.2b.1 ***Incremental field air and water inspection and testing of subassemblies.*** The incremental field air and water testing of subassemblies of all building exterior enclosure elements should be a standardized practice on projects of all sizes. The "Incremental" concept signifies testing of critical air and water management enclosure components, such as air barriers, window and door air and water seals, flashings, etc. while those components are still visible and before those components are buried or covered up by other construction in a completed assembly, so that repairs can be done effectively and inexpensively.

U.2b.1.1 During team selection, a criterion in the owner's selection of the architect should include the architect's track record in specifying the incremental and final field water testing of the full range of exterior enclosure elements. Likewise, a criterion in the owner's selection of the General Contractor or Construction Manager should include their track record in designing and successfully carrying out incremental field water testing of all building exterior enclosure elements.

U.2b.1.2 During design, Owners should be informed that water leakage can be a source of significant problems downstream, and that incremental field water testing is a practical, low-tech, and low cost means of identifying and avoiding such leaks. Owners should be made aware that eliminating such testing as a result of value engineering or other cost cutting measures during construction could result in significant costs and potential health hazards later during building operations. Air leakage can result in condensation, mold, rust, decay, indoor air quality problems, premature failure of enclosure assemblies, and is a major source of energy loss.

U.2b.1.3 Construction documents for the building exterior enclosure should include specific provisions for planning and accomplishing the incremental field water testing being recommended in this sub-annex.

U.2b.1.4 The scope of air barrier and building assembly testing for air leakage and air barrier continuity should be discussed with the Owner, and included in the specifications. A list of such inspections and testing is included herein.

Coordination is required between subcontractors to provide continuity of an air barrier system and achieve an airtight building enclosure; the interconnections between materials and assemblies of materials and the penetrations should be a focus. Determining who is responsible for the interface joint between the different air barrier system assemblies, where one trade stops and the other starts, and the trade responsible for the joint between the two is vital. Determining who is responsible for sealing penetrations should be established. Sequencing construction operations so that the joints are accessible and constructible is an important milestone discussion in a commissioning process

U.2b.1.5 Each manufacturer should provide specific instructions for the incremental field water testing of subassemblies within the installation instructions for its exterior enclosure products.

U.2b.1.6 Prior to the construction of the exterior enclosure, the general contractor or construction manager should develop an incremental field water testing program as part of its quality control program for the building's exterior enclosure, including a checklist for all exterior enclosure subassemblies to be tested, including those listed in Section U.2b.1.2.

U.2b.1.7 During the construction of the exterior enclosure, the general contractor or construction manager should be responsible either for (1) accomplishing the incremental field water- testing program developed in U.2b.1.2 above or (2) explicitly delegating each element of the incremental testing to a subcontractor.

U.2b.1.8 All leaks identified should be entered into the Issues Log, per Section 7.2 of this Guideline, and the issue should be resolved and the resolution documented. All negative tests (those with no leaks) should be recorded, signed by the responsible organization, and submitted into the construction documentation.

U.2b.2 ***Applicable subassemblies to be tested.*** Incremental field water testing should be accomplished for all materials included in the building's exterior enclosure, including at least the field subassemblies of individual components listed below. A person with a water bottle or a water hose without a nozzle should be able to conduct such tests.

(a) For masonry, EIFS, Stucco - Base flashing laps, inside corners, outside corners, end dams, lintel flashing laps, end dams;

(b) For doors, fenestration / curtain wall - sub-sill flashings, laps, end dams, window head flashings

(c) Thru wall flashing terminations, gutters;

(d) Expansion joint gutters;

(e) Parapet flashing laps, penetrations, inside and outside corners.

(f) Roofing

(g) Below grade waterproofing.

U.2b.3 ***For lab prequalification and field quality control of air barrier materials, assemblies and the whole building,*** the following testing and inspection protocols are available and the scope should depend on the owner's budget and the functional importance of the building enclosure's air-tightness:

a. Qualitative Testing and Inspection:

1) Daily reports of observations, with copies to the Owner, Contractor and Architect.

2) Continuity of the air barrier system throughout the building enclosure with no gaps, holes.

3) Structural support of the air barrier system to withstand design air pressures.

4) Masonry and concrete surfaces are smooth, clean and free of cavities, protrusions and mortar droppings, with mortar joints struck flush, or as required by the manufacturer of the air barrier material.

5) Site conditions for application temperature and dryness of substrates.

6) Maximum length of exposure time of materials to ultra-violet deterioration.

7) Surfaces are properly primed.

8) Laps in material are 2"minimum, shingled in the correct direction (or mastic applied on exposed edges), with no fishmouths.

9) Mastic applied on cut edges.

10) Roller has been used to enhance adhesion.

11) Measure application thickness of liquid-applied materials to manufacturer's specifications for the specific substrate.

12) Materials used for compatibility.

13) Transitions at changes in direction, and structural support at gaps.

14) Connections between assemblies (membrane and sealants) for cleaning, preparation and priming of surfaces, structural support, integrity and continuity of seal.

15) All penetrations sealed.

b. ASTM E 1186/98 "Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Retarder Systems."

1) Infrared scanning with pressurization/depressurization.

2) Smoke pencil with pressurization/depressurization.

3) Pressurization/depressurization with use of anemometer
4) Generated sound with sound detection
5) Tracer gas measurement of decay rate
6) Chamber pressurization/depressurization in conjunction with smoke tracers
7) Chamber depressurization using detection liquids

c. **Quantitative tests**:

1) Provide written test reports of all tests performed, with copies to the Owner, Contractor and Architect.
2) Material compliance for maximum air permeance, ASTM E 2178.
3) ASTM E 283 (Lab test), Determining rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors under Specified Pressure Differences Across the Specimen.
4) Assemblies, ASTM E 2357 or E1677 (lab tests), as the case may be, test pressure and allowable air leakage rate to be determined by design professional for interior design conditions and location of project.
5) CAN/CGSB 1986 Standard 149.10, Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method.
6) CAN/CGSB 1996 Standard 149.15 Determination of the Overall Envelope Airtightness of Office Buildings by the Fan Depressurization Method Using the Building's Air Handling System.
7) Canadian National Master Specification Sections 07272 Air Barrier Systems for Exterior Walls of Low-Rise Buildings.
8) Canadian National Master Specification 07272.1 : Durability Assessment of Bead-Applied Urethane-Based Sealant Foam for Air Barriers.
9) Whole building, floors, or suites, ASTM E779, Determining Airtightness of Buildings Air Leakage Rate by Single Zone Air Pressurization.
10) Windows, doors and sealed connections to adjacent opaque assemblies, ASTM E783
11) Tracer gas testing, ASTM E741
12) Pressure test, ASTM E330
13) Bond to substrate, ASTM D4541-95
14) Minimum dry or wet film thickness for liquid-applied materials are per the manufacturer's requirements.

U.2b.4 Commentary About Limits of Current Practice

U.2b.4.1 ***Accepted Practice.*** It has become an accepted practice during construction that the field water testing of the exterior enclosure waits until a 'completed assembly' is available for testing. This might include multiple single components of a single interfacing material plus multiple installed interfacing exterior wall materials.

U.2b.4.2 ***AAMA 501.2 hose test and ASTM E1105 test methods.*** These methods have become standardized field water testing procedures in the field during construction. ASTM E 783 for air leakage is performed using the same set-up and equipment as ASTM E 1105. Such field air and water testing is required to provide quality assurance documentation that the installed exterior enclosure materials meet the functional requirements of the contract documents. Relying on the AAMA hose test and ASTM air and water field-testing is a contractual necessity for walls because the wall performance requirements are specified within the specifications.

U.2b.4.3 ***Standardized Wall Systems.*** Where standardized wall systems are utilized, the AAMA and ASTM tests are appropriate field tests to confirm correct installation. Where either modified standard systems or custom system applications are utilized, then lab testing and/or rigorous field-testing is required.

U.2b.4.4 ***Too Late in Process.*** The testing of the 'completed assembly' using AAMA 501.2 and ASTM E 1105 and E 783 may be too late in the process. If this field water testing of the 'completed assembly' determines that there is leakage thru the installed exterior assembly, then disassembly is needed of the single material installation / or the disassembly of the multiple interfacing materials in order to find the 'root cause' of the leakage issue. This typically involves (1) stripping the wall down, and (2) performing selective forensic demolition to observe the defects of the constructed wall. This process can be expensive, and time-consuming. It is also unnecessary in most cases if incremental field water- testing of sub-assemblies is done before the 'completed assembly' is built up.

U.2b.4.5 ***Opportunity Lost.*** The field water testing of the exterior enclosure subassemblies is important to do, but unfortunately is seldom done. Thus, the purpose of section 1 above is to provide "good practice" recommendations for incrementally conducting such field water testing.

Functional Test

WINDOWS & DOORS

1. Participants

Commissioning Agent (CxA): ___________________________ of CxGBS

Sealant contractor: ____________________________________ of Metro Waterproofing

Glazing contractor: ___________________________________ of H & B Storefront

General contractor: ___________________________________of Hardin/Humphries

Owner's rep.: ____ of Darden & Company

Party filling out this form and witnessing testing ___________________________________

Date of test _______________________________

2. Test Prerequisites

a. __ The building envelop construction checklists have been submitted and approved indicating that the contractors are ready for functional testing of:

Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______

Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______

Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______

Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______

b. __ All A/E punch list items for these sections of the fenestration system have been corrected.

c. __ This functional test procedure has been reviewed and agreed to by installing contractors.

d. __ Testing schedule attached

e. __ Equipment required for access has been coordinated with test schedule.

f. __ Water connection for hose is available and has adequate pressure required for test.

g. __ If area to be tested has previously failed testing Form C-6 (Commissioning Corrective Action Report) has been completed by contractor indicating corrections are complete and system is ready for retesting.

3. Verification of Associated Construction Checks.

Associated construction checklist and reports for systems being functionally tested are successfully completed. Pass? Y / N

4. Testing Procedures and Record

Procedure No.	Test Procedure[3] (including special conditions)	Expected and Actual Response [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
1	Field test installed fenestration components as directed by CxA in accordance with AAMA 501-94 Method of Test for Exterior Walls. Standard Test Method for Field Determination of Water Penetration of Exterior Windows, Curtain Walls and Doors.	No water leakage.		

AAMA 501.2 test method contained in AAMA 501-94 consists of a spray test made with a ¾" diameter hose and special nozzle from Monarch Nozzle directed at the test section perpendicular to the face of the wall. The nozzle is moved slowly back and forth over approximately 5 linear feet of the system component being tested at 1 foot from the exterior surface of the wall for a 5 minute period.

Working from the exterior the test section shall be selectively wetted starting from the lowest horizontal framing member and rising in a vertical progression as each element of the assembly is tested for the required duration of one minute per foot along the horizontal and vertical components of the assembly being tested. During the hose testing procedure pressure to the nozzle must be maintained at a minimum of 30 psi and a maximum of 35 psi at the nozzle inlet.

If leakage has occurred at any point, the framing shall be taped at such points to prevent further leakage of these points during subsequent testing of adjacent joints and framing. The process shall test all framing, thresholds, gaskets and joint intersections in increments of exposed length not exceeding 6 ft and always working upwards on the wall.

ATTACH A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING

END OF CHECKLIST

A. Numbering Key for Commissioning Procedures

The checklists, Tests, documentation and training use the following identification numbering:

At the beginning of the identification number is a text abbreviation for the following:

Document or Event Abbreviations

DOC	=	Documentation
CK	=	Construction Checklist
IP	=	Installation Plan
FT	=	Functional Test
R	=	Review
TR	=	Training Record

Numbering Key

Test-1102.3: The first four digits uniquely identify the assembly and each component tested. The first 2 digits are the System Type, the second 2 digits are an arbitrary component number. The number after the decimal is the test number. For example, Test-1102.3 = Test 3 of the stone sill flashing and weeps, component number 2 (e.g., 1102.3 = Wood window component #2, FT #3, because wood window is system Type 11). The component number of 00 means "general" or "all" components, as with the entire system. All tests, procedures, training and records should have the same first 4 digits for any given component.

Number system tests as follows:

1100	Wood Windows	1200	Wood Doors
1101	Subsill & sealant to stone sill	1201	Threshold, drainage mat, and pan
1102	Stone sill flashing & weeps	1202	Interior Drain
1103	Left jam & sealant to stone surround /Jam	1203	Left jam & sealant to stone surround /Jam
1104	Right jam & sealant to stone surround /Jam	1204	Right jam & sealant to stone surround /Jam
1105	Window head, sealant & weeps	1205	Door head, sealant & weeps
1106	Glass mullions	1206	Glass mullions

Functional Test

MOCK UP WINDOW

1. Participants

Commissioning Agent (CxA): ___________________________ of CxGBS

Sealant contractor: ____________________________________ of Metro Waterproofing

Glazing contractor: ___________________________________ of H & B Storefront

General contractor: ___________________________________of Hardin/Humphries

Owner's rep.: ____ of Darden & Company

Party filling out this form and witnessing testing ___________________________________

Date of test _______________________________

2. Test Prerequisites

a. __ Relevant sections of the building envelop construction checklist has been submitted and approved indicating that the contractors are ready for testing of:

Location: ______ Elevation ______ Floor; ________ From grid line _______ to grid line ______

b. __ This test procedure has been reviewed and agreed to by installing contractors.

c. __ Testing schedule attached

d. __ Equipment required for access has been coordinated with test schedule.

e. __ Water connection for hose is available and has adequate pressure required for test.

f. __ If area to be tested has previously failed testing Form C-6 (Commissioning Corrective Action Report) has been completed by contractor indicating corrections are complete and system is ready for retesting.

3. Verification of Associated Construction Checks.

Associated prefunctional checklist and reports for systems being tested are successfully completed. Pass? Y / N

4. Testing Procedures and Record

Procedure No.	Test Procedure[3] (including special conditions)	Expected and Actual Response [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
1	Field test installed fenestration components as directed by CxA in accordance with ASTM E783-93 Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors. The ASTM E783 test shall be conducted at an air pressure difference of 6.24 lbs/ft^2.	The maximum allowable rate of air leakage must not exceed .3 ft^3/min./ft^2.		
2	Field test installed fenestration components as directed by CxA in accordance with ASTM 1105-96 Standard Test Method for Field Determination of Water Penetration of Exterior Windows, Curtain Walls and Doors by Uniform or Cyclic Static Air Pressure Difference. The ASTM 1105 test shall be conducted at an air pressure difference of 6.24 lbs/ft^2.	No water leakage.		
3	Field test installed fenestration components as directed by CxA in accordance with AAMA 501-94 Method of Test for Exterior Walls. Standard Test Method for Field Determination of Water Penetration of Exterior Windows, Curtain Walls and Doors.	No water leakage.		

ATTACH A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING

END OF CHECKLIST

Test Procedure

EXTERIOR LOUVERS & GRILLS

1. Participants

Commissioning Agent (CxA): ____________________________ of CxGBS

Sealant contractor: _____________________________________ of Metro Waterproofing

Sheet metal contractor: __________________________________of A&R Welding

General contractor: ____________________________________of Hardin/Humphries

Owner's rep.: ____ of Darden & Company

Party filling out this form and witnessing testing ____________________________________

Date of test ________________________________

2. Test Prerequisites

a. __ The building envelop prefunctional checklists have been submitted and approved indicating that the contractors are ready for functional testing of:

Location: 3rd floor porch above main entry north louver/grill ____

Location: 3rd floor porch above main entry south louver/grill ____

Location: Parking level north elevation louvers/grills below fitness center ____

Location: 1st floor south elevation west corner louver/grill ____

Location: Emergency generator louver/grill ____

b. __ All A/E punch list items for these sections of the building envelop system have been corrected.

c. __ This test procedure has been reviewed and agreed to by installing contractors.

d. __ Testing schedule attached

e. __ Equipment required for access has been coordinated with test schedule.

f. __ Water connection for hose is available and has adequate pressure required for test.

g. __ If area to be tested has previously failed testing Form C-6 (Commissioning Corrective Action Report) has been completed by contractor indicating corrections are complete and system is ready for retesting.

3. Verification of Associated Construction Checks.

Associated construction checklist and reports for systems being tested are successfully completed. Pass? Y / N

4. Testing Procedures and Record

Procedure No.	Test Procedure[3] (including special conditions)	Expected and Actual Response [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
1	Field test installed fenestration components as directed by CxA in accordance with AAMA 501-94 Method of Test for Exterior Walls. Standard Test Method for Field Determination of Water Penetration of Exterior Windows, Curtain Walls and Doors.	No water leakage.		

AAMA 501.2 test method contained in AAMA 501-94 consists of a spray test made with a ¾" diameter hose and special nozzle from Monarch Nozzle directed at the test section perpendicular to the face of the wall. The nozzle is moved slowly back and forth over approximately 5 linear feet of the system component being tested at 1 foot from the exterior surface of the wall for a 5 minute period.

Working from the exterior the test section shall be selectively wetted starting from the lowest horizontal framing member and rising in a vertical progression as each element of the assembly is tested for the required duration of one minute per foot along the horizontal and vertical components of the assembly being tested. During the hose testing procedure pressure to the nozzle must be maintained at a minimum of 30 psi and a maximum of 35 psi at the nozzle inlet.

The process shall test the assembly including louvers, all framing, and joint intersections in increments of exposed length not exceeding 6 ft and always working upwards on the wall.

ATTACH A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING

END OF CHECKLIST

Annex U.3a: Reference Standards for Field Testing

Commentary

This sub-annex contains a list of reference standards for testing and evaluation of building exterior enclosures.

Credits

The contents of this sub-annex have been compiled by William Nash.

This sub-annex contains a list of reference standards from ASTM and AAMA for field-testing applications.

U.3a.1 ASTM Standards

ASTM C1601 "Standard Test Method for Field Determination of Water Penetration of Masonry Wall Surfaces."

ASTM E 783 "Standard Test Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors."

ASTM E1105 "Standard 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."

ASTM E1677 "Standard Specification of an Air Retarder (AR) Material or System for Low Rise Framed Building Walls:

ASTM (Reapproved 1997), Standard Designation: C 1060-90 Standard Practice for Thermagraphic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings, Committee C-16.30, American Society for Testing and Materials, West Conshohocken, PA

ASTM (1999) Standard Designation: E 779-99, Standard Test Method for Determining Air Leakage Rate by Fan Pressurization, American Society for Testing and Materials, West Conshohocken, PA.

ASTM (2000) Standard Designation: E 1105-00, Standard Test Method for Field Determination of Water Penetration of Installed Exterior windows, Skylights, Doors, and Curtain Walls, by Uniform cyclic Static Pressure Difference, American Society for Testing and Materials, West Conshohocken, PA.

ASTM (2002) Standard Designation: F 2170-02, Standard Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes, American Society for Testing and Materials, West Conshohocken, PA.

ASTM (2003) Standard Designation: F 1869-03, Standard Test Method for Measuring Vapor Emission Rate of Concrete Sub flooring Using Anhydrous Calcium Chloride, American Society for Testing and Materials, West Conshohocken, PA.

U.3a.2 AAMA Standards

AAMA 501.2 "Quality Assurance of Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems."

AAMA 502 “Voluntary Specification for Field Testing of Windows and Sliding Glass Doors.”

AAMA 503 “Specification for Field Testing of Metal Storefronts, Curtain Walls, and Sloped Glazing Systems.”

Annex U.3b: Technical Information Resources

Commentary

This sub-annex contains a list of sources of technical information for testing and evaluation of building exterior enclosures.

Credits

The contents of this sub-annex have been compiled by William Nash.

U.3b.1 List of Technical Sources

The Sealant, Waterproofing and Restoration Institute “Sealants: The Professionals’ Guide”, Sealant, Waterproofing and Restoration Institute.

SEI/ASCE-7-02 Minimum Design Loads for Buildings and Other Structures

SEI/ASCE 37-02 Design Loads on Structures during Construction

Technical Notes on Brick Construction – Brick Institute of America (Binder)

TEK Manual for Concrete Masonry Design and Construction – National Concrete Masonry Association (NCMA) (Binder)

The Complete Concrete, Masonry and Brick Handbook, Adams, 1983, Van Nostrand Reinhold

Masonry Inspectors Workbook – Masonry Institute of American (MIA)

Masonry Structures – The Masonry Society (TMS)/Second Edition/Classnotes

Reinforced Concrete Masonry Construction – Inspector’s Handbook (MIA)

Concrete Masonry Handbook for Architects, Engineers, Builders – Portland Cement Association/1991/W.C. Panarese, S.H. Kosmatica, F.A. Randall, Jr.

Building Code Requirements for Masonry Structures (ACI 530-95/ASCE 5095/TMS 402-95)

Specification for Masonry Structures (ACI 530.1-95/ASCE 6-95/TMS 602-95)

Waterproofing the Building Envelope/Kubal/1993/McGraw-Hill

Masonry & Steel Detailing Handbook, Walter Laska, Aberdeen Group, 218 pages, 1993

Nondestructive Evaluation & Testing of Masonry, Bruce A. Suprenant and Michael P. Schuller, Aberdeen Group, 1994, 194 Pages

Portland Cement Plaster (Stucco) Manual, Melander & Isberner, 1996, Portland Cement Association.

Moisture Control in Buildings, ASTM Manual, 18, H.R. Treschsel Editor, 1994

Modern Stone Cladding, Michael D. Lewis, ASTM Manual 21, Design and Installation of Exterior Dimension Stone Systems, 1995

Standard 11-90, American Society for Civil Engineers, Guideline for Structural Condition Assessment of Existing Buildings, 1991.

Building Restoration and Maintenance Manual, Sealant, Waterproofing and Restoration Institute. (SWRI)

Handbook of Construction Tolerances, David Kent Ballast, McGraw Hill, 1994

Moisture Control Handbook, Carmody and Lstiburek, John Wiley and Sons, 1994

Sealant Manual, United Professional Caulking and Restoration

Structural Steel Inspection and Field Practices Workbook, ICC, May 2003

Design Loads on Structures During Construction, SEI/ASCE 37-02, 2002

Minimum Design Loads for Buildings and Other Structures, SEI/ASCE 7-02, ASCE, 2003

Construction Quality Management for Contractors, US Army Corps of Engineers

ASTM Standards in Building Codes – ASTM

ACI Manual of Concrete Practice – American Concrete Institute

The Fundamentals of Cleaning and Coating Concrete, Society for Protective Coatings, 2001

The Inspection of Coatings and Linings –Society for Protective Coatings SSPC-03-14-2003

SSPC Painting Manual, Good Painting Practice, 2002

Annex U.3c: Testing Resources By Wall Assembly

Commentary

This sub-annex contains a list of sources of testing resources by wall assembly.

Credits

The contents of this sub-annex have been compiled by William Nash.

U.3c.0 Below Grade Waterproofing

1.1 Testing is performed of Terminations, the field of the wall, and penetrations thru the waterproofing.

1.1.1 Hose Testing is used – A hose and garden nozzle

1.1.2 Flood Testing – of exterior walls can be used depending upon backfill sequencing

0.1.0 References

www.wrgrace.com

www.carlisle.com

www.sarnafilus.com

1.3 Checklist

1.3.1 Submittals require formal submittal of installation instructions, material storage instruction, shop drawings + details, termination isometrics

1.3.2 Include in field mock up

U.3c.0 Air Retarders, Weather Resistive Barriers (WRB), Vapor Retarders

2.1 The workmanship of the installation is dependent upon multiple repetitive operations.

2.2 AAMA 501.2

2.3 Testing – Air and Water. The installation of air retarders, weather resistive barriers, and vapor retarders must be for the manufacturer's installation instructions. A standard installation practice is to install role products in a single fashion from bottom to the top. A hose + garden nozzle can be used to test.

2.4 References – Air Barrier Association and America (AABA), WR. Grace

www.airbarrier.org

www.wrgrace.com

http://www.construction.tyvek.com/

2.5 Checklists

2.5.1 Require the formal submittal of material storage instructions and installation instructions + shop drawings + details + terminations + isometrics

2.5.2 Include in field mock up

U.3c.0 Flashing

3.1 Workmanship – Flashing are made from varying types of materials – Metal – copper, aluminum, zinc, stainless steel, - Peel n stick, - Roll products/sheets goods these materials are available in varying widths and lengths.

3.2 Testing – water, end dams, outside corners, inside corners, lintels, base

3.3 Water Bottle, Hose as flashing is installed it should be water tested at lap joints, end, dams, inside corners, outside corners. A water bottle or a hose can provide water to test these installations.

3.4 References – BIA, AAMA, EIFS

www.bia.org Brick Institute of America (BIA)

www.aaamanet.org American Architectural Manufacturers Association (AAMA)

www.eifshotline.org EIFS

www.wrgrace.org

http://www.construction.tyvek.com/ Flashing Institute Guidelines

3.5 Checklist

1. Submittals – Material Storage + Installation Instructions
2. Include flashing in field mock up
3. Shop drawings, isometrics of end dams, flashings, inside corners, outside corners, terminations

U.3c.0 Masonry Wall Systems – Brick, Limestone, Granite, Concrete Block

4.1 Workmanship is inclusive of flashings, end dams, corners – inside and outside, structural attachment.

4.2 Testing – water penetration, air penetration resistance.

0. ASTM E 1601 Field Testing for Water Leakage through Masonry
0. ASTM E 1105 "Standard 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"
0. AAMA 501.2.03 – Quality Assurance and Diagnostic Water Leakage Field Check of installed storefronts, curtain walls, and sloped glazing systems.
0. lashing – Base and Lintel

3.1.4 References

WWW.BIA.ORG

WWW.NCMA.ORG – National Concrete Masonry Association

Brick Institute of America (BIA), ASTM, ASTM Manual 21

Modern Stone Cladding, Michael D. Lewis

Indiana Limestone Handbook, Indiana Limestone Institute of America 21st Edition

5. Checklists

6.1 Submittals Material storage + installation instructions + shop drawings + specific shapes + flashing + isometrics

6.2 Include mock up submittal

U.3c.0 Exterior Insulation and Finish Systems (EIFS)

5.1 Workmanship a certified installer must be used, an experienced installer with the specific EIFS product should be used

5.2 Testing

1. ASTM E 1105 “Standard 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”
2. AAMA 501.2 - Hose

5.3 References –

Exterior Design Institute (EDI), ASTM

WWW.EIFSHOTLINE.ORG

WWW.EXTERIOR-DESIGN-INST.COM

WWW.ASTM.ORG

4.2.0 Checklists

0. Submittals – Material storage + installation instructions + shop drawings + flashings – window head, window sill and jambs + terminations + ismetrics

0. Include windows + flashings in field mock up of EIFS

0. Exterior Insulation and Finish System Design Handbook Robert G. Thomas Jr.

0. ASTM Manual – Mark Williams, Barbara Williams

U.3c.0 Cement Stucco Systems

6.1 Workmanship

6.2 Testing Air and Water Penetration

1. ASTM E 1105 “Standard 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”
2. AAMA 501.2 – A hose + a garden nozzle can be used to spray interfacing materials and wall penetrations

6.3 References

Portland Cement Association (PCA)

PCA – WWW.CEMENT.ORG Stucco

WWW.NWCB.ORG Northwest Wall and Ceiling Bureau

Portland Cement Plaster (Stucco) Manual – Portland Cement Association By John M. Melander and Albert W. Isberner, Jr.

Portland Cement Plaster – Stucco-Resource Guide/Northwest Wall and Ceiling Bureau

6.4 Checklists

1. Submittals – Material storage + Installation Instructions + shop drawings + details + flashings + terminations + isometrics

    2. Field mock up

U.3c.0 Aluminum and Glass Curtain Wall Systems

7.1 Workmanship Material interface to tolerances can effect installation

7.2 Testing – Water penetration and air penetration

0. ASTM E 1105 “Standard 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”
0. AAMA 501.2 “Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems”
0. AAMA 502 “Voluntary Specification for Field Testing of Windows and Sliding Glass Doors”
0. AAMA 503 “Specification for Field Testing of Metal Storefronts, Curtain Walls and Sloped Glazing Systems.
0. ASTM E 783 “Standard Test Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors”

7.2 References

WWW.AAMANET.ORG

AAMA, GANA

6.2.0 Checklists

0. Submittals – Installation instructions, shipping and storage instructions
0. Submittals – Field Water Testing
0. Submittals – Shop Drawings, Flashings, Terminations, Isometrics

U.3c.0 Metal Panels

8.1 Workmanship

8.2 Testing – Air and Water

1. ASTM E 1105 “Standard 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”

2. AAMA 501.2-03 – Hose testing of interfacing materials and metal-to-metal panel joints.

8.3 References

www.alucobond.com

www.alcoa.com

8.4 Checklists

Submittals – Installation instructions, shop drawings, details, isometrics

U.3c.0 Precast Concrete Panels/Glass Fiber Reinforced Concrete (GFRC)/Unitized Panels – Brick Clad, Panels, Limestone

9.1 Workmanship/Installation – Heat, Air, Mositure – Vapor + Liquid

9.2 Testing – Air and Water Penetration

1. ASTM E 1105 "Standard 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"
2. AAMA 501.2 "Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls and Sloped Glazing Systems" – Hose testing of interfacing material joints

9.3 References

http://www.pca.org/

Tolerance Manual for Precast and Pre-stressed Concrete Construction, MNL 135-00, Precast/Pre-stressed Concrete Institute.

Recommended Practice for Glass Fiber reinforced Concrete Panels, MNL-128-01, Precast/Pre-stressed Concrete Institute.

9.4 Checklists

1. Submittals – Shop Drawings, Installation Instructions, Flashing, Interfacing Details, Isometrics

U.3c.0 Sealant Joints

10.1 Workmanship Interfacing Materials, differing materials move because the change of temperature

10.2 Water and Adhesion Testing

1. AAMA 501.2 "Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls and Sloped Glazing Systems"
2. Adhesion Testing - ASTM

10.3 References – Sealant Manual – United Professional Caulking and Restoration Inc.

www.tremcosealants.com

http://www.dow.com/

10.4 Checklist

1. Material Data Sheets for Sealant

U.3c.0 Sheet Metal, Parapet Caps, Metal Shingles, Gutters

Workmanship – Heat, air and moisture (vapor + liquid) must be inspected and tested

11.1 AAMA 501.2 Testing – Water Penetration hose testing of sheet metal, parapet caps, metal shingles, diverters, gutters can be performed by spraying with a hose + garden nozzle

11.2 References

http://www.smacna.com/

11.3 Checklist

Submittals – shop drawings, details, terminations, isometrics

U.3c.0 Expansion Joints

Workmanship/Tolerances can effect installation

12.1 Testing – Air and Water Penetration, Thermal - Heat, Air and moisture (vapor + liquid) must be tested/inspected. AAMA 501.2 – Hose Testing

12.2 References:

www.situra.com

12.3 Checklists

Submittals – Shop Drawings, Installation Instructions

U.3c.0 Roofing

13.1 Testing – Air and Water, Thermal

13.1.1 Hose Testing – Spray testing of mechanical curbs, parapets, penetrations, flashings

13.1.2 Flood Testing – The structural engineer must be consulted and formal permission obtained prior to any flood testing of roofing systems.

13.2 References

www.carlisle.com

www.firestone.com

www.chemlinkinc.com

www.sopremaworld.com

www.siplast.com

www.rci-mecury.com

13.3 Checklist

Submittals – Shop drawings, flashings, curbs, parapets, penetrations

Non-Conformance Management

The following outlines the procedure for controlling the identification, documentation, evaluation, dispositioning, notification, segregation, re-inspection and prevention of the inadvertent use or installation of non-conforming items of work.

Construction materials and permanent plant equipment which are found not to be in compliance with the approved project requirements of applicable specifications, drawings, codes and standards and which render the quality of the materials or equipment unacceptable or indeterminate shall require the generation of a Non-Conformance Report (NCR), (Exhibit 01.). NCR's are deficiencies which can't be resolved within the requirements of existing procedures. Field supervision should demonstrate to the Site Quality Team that existing procedures/instructions do or do not exist for correction of deficiencies.

An item incurring a deficiency that can be corrected while maintaining compliance to requirements (including any work process procedure requirements), does not constitute a non-conformance and is considered as "unsatisfactory".

Non-Conformances typically include:

- Physical defects in materials and equipment
- Failures of required tests
- Incorrect or inadequate documentation
- Departures from approved work processes, inspection or testing procedures

Non-conformities that may impair safety, assembly sequence, commissioning or schedule dead-lines shall be treated with absolute priority with the corresponding corrective actions.

1.0The SQM or designee has the following repsonsiblities:

1.1 Determine, in coordination with engineering, when a construction problem constitutes an unsatisfactory or non-conforming condition

1.1.1-Initiate a Non-Conformance Report (NCR) as conditions warrant.

1.1.2Initiate a stop work order if required

1.1.3-Identify, in conjunction with the inspectors and field supervision, non-conforming materials, parts, components, or installations at the project site.

1.1.4 Maintain the Site Non-Conformance Report log (Exhibit 01.). The log shall be distributed on a periodic basis – at least weekly to the Architect, Project Manager,Subcontractor Project Managers, Site Engineers, and the appropriate project management representatives as designated in the distribution of project documentation in the project's site specific quality plan.

1.1.5Facilitate the disposition for closure of Non-Conformance Reports and report in the NCR Log.

1.1.6 Facilitate the resolution to correcting unsatisfactory items of work.

2.0 The Site Project Managers have the following responsibilities:

2.1.1-Assist the Site Quality Team in performing inspections for determination if any part of the work or delivered materials may be non-conforming or unsatisfactory.

2.1.2Assist in determining the corrective action or disposition for non-conforming or unsatisfactory work or processes.

2.2 Ensure that any non-conforming materials or equipment are segrated or tagged until disposition has been determined.

2.2.1 Assist Site Quality Team to assure that the performance of inspections and verifications ensure that subcontractor's work complies with the subcontract and project drawings and specifications. Upon notice of an unacceptable condition by the subcontractor, the Project Manager with the Site Quality Team shall determine whether the condition is non-conforming or unsatisfactory.

2.2.2 The Site Project Managers, with the input of the Engineers and Quality team shall continually review site processes and work operations to mitigate the occurance of Non-Conformances.

2.3 The following is the general guidelines for the Non-Conformance Program:

2.3.1 For materials or equipment identified as non-conforming, a NCR shall be generated with all appropriate documentation assembled – pictures, specifications, test/inspection reports etc. A Hold tag shall be placed on the work. Material or equipment shall be removed to a segregated area to prevent inadvertent use.

2.3.2 NCR shall be recorded in the NCR Log.

2.3.3 Determine the person or group to provide the acceptable disposition of the non-conforming issue. NCR's can be grouped into two categories

For Owner materials or equipment receive authorization prior to rejecting or returning to supplier.

2.3.3.1 Category B NCR's: Require only MCI approval of NCR disposition. The Owner and MCI Quality Manger shall be distributed on all Category B NCR's. The following "Proposed Dispositions" are considered Category B:

REWORK – This disposition would allow correction of the NCR condition by using the same or equivalent process which was used in the construction, manufacturing, or erection of the item so that the item will meet the original requirements of the contract documents.

REJECT – This disposition would allow for the reject of work, materials or equipment when the non-conforming item cannot be REPAIRED, USE AS IS, or RETURN TO SUPPLIER.

2.3.4 Once the Disposition has been determined and accepted the NCR and Log shall be updated.

2.3.5 If required the defined corrective work shall be completed.

2.3.6 Upon confirming completion of the assigned disposition the SQM or other appropriate official shall inspect the work and verify completion and complete FINAL ACCEPTANCE section the balance of the NCR form .

2.3.7 If the rework or repair is unacceptable the NCR remains open until the work is acceptable

2.3.8 Any non-conformance caused by re-work/repair other than the original non-conformance , shall be documented as a new NCR.

2.3.9 Any changes required in site procedures and processes resulting from corrective disposition to a NCR shall be recorded, and distributed to all appropriate parties. that will assist with determining the appropriate party to provide disposition acceptance:

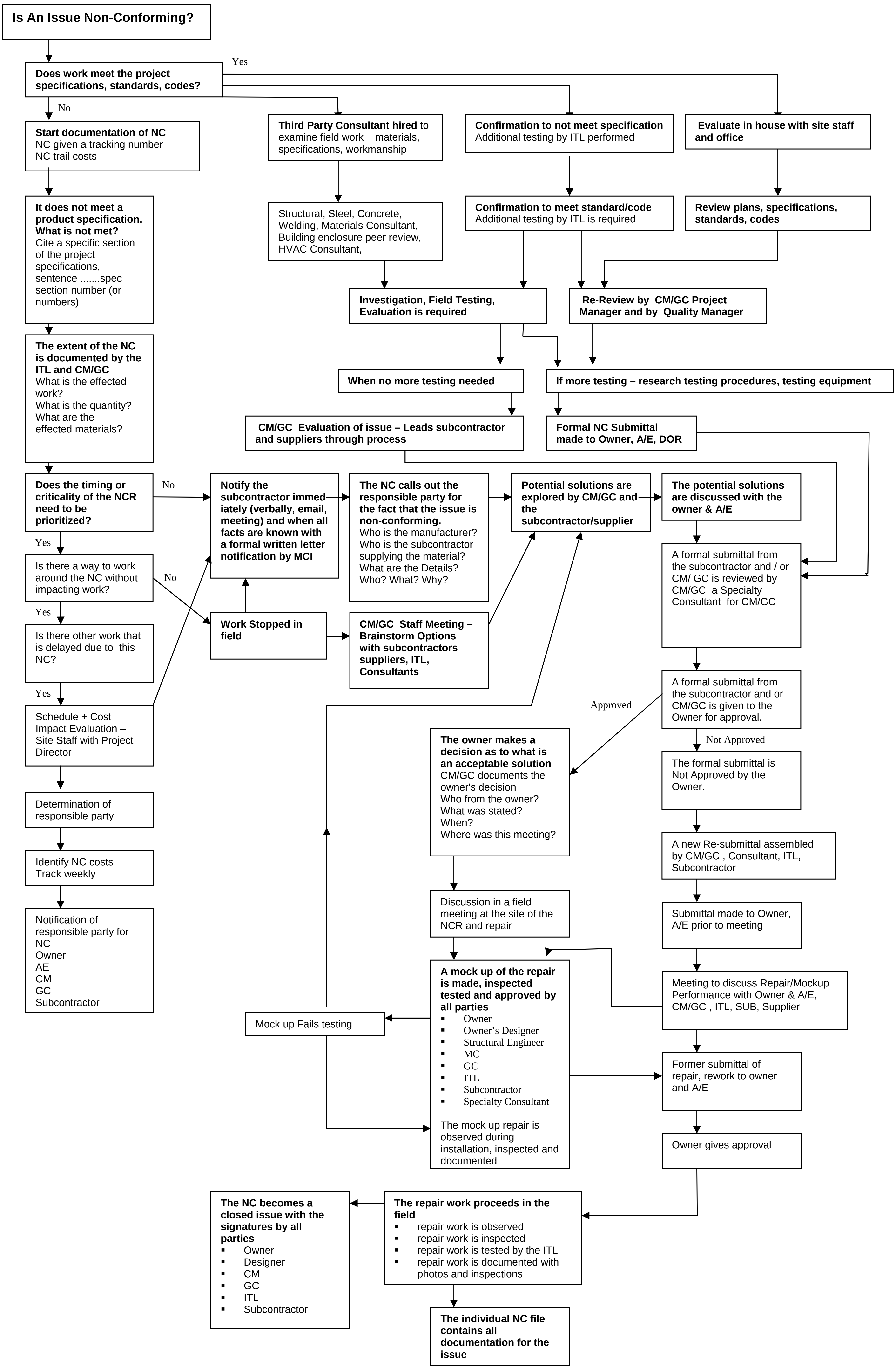
2.3.9.1 Category A NCR's: Require Owner/Design Engineer approval of NCR disposition. The following "Proposed Dispositions" are considered Category A:

USE AS IS – This allows the use of the Non-conforming item without correction of the non-conformance,

REPAIR – This allows the use of a repair process or procedure so that the capability of the item to function reliably and safely is unimpaired, even though the item still does not conform to the original requirements

2.3.10 REJECT/RETURN TO SUPPLIER – This is for OWNER supplied equipment. This case is for non-conforming items that cannot be repaired, re-worked or used as is.

Non-Conformance Flow Chart



National Institute of BUILDING SCIENCES

1090 Vermont Avenue, NW Suite 700
Washington, DC 20005-4950
Phone: (202) 289-7800
Fax: (202) 289-1092
www.nibs.org