



# GUIDELINE

ASHRAE Guideline 1.1-2007R

**Public Review Draft**

## **Proposed Revision of Guideline 1.1-2007, Application of the Commissioning Process to New HVAC&R Systems**

**Second Public Review (September 2024)  
(Complete Draft for Full Review)**

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at <https://www.ashrae.org/technical-resources/standards-and-guidelines/public-review-drafts> and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at [www.ashrae.org/bookstore](http://www.ashrae.org/bookstore) or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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**(This foreword is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)**

## **FOREWORD**

*The Commissioning Process (Cx) is a quality-oriented process for verifying and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria. The Commissioning Provider (CxP) Team uses a variety of methods and tools to verify that a project is achieving the Owner's Project Requirements (OPR) throughout the delivery of the project.*

*Commissioning process procedures and requirements for the CxP Team are fully covered in ASHRAE Guideline 0, The Commissioning Process for New Buildings and New Systems. That document provides adequate guidance for implementing the Cx for all building assemblies and systems for new buildings. Refer to ASHRAE Guideline 0.2, Commissioning Process for Existing Systems and Assemblies, and ASHRAE Guideline 1.2, Technical Requirements for the Commissioning Process for Existing HVAC&R Systems and Assemblies, for commissioning of existing buildings.*

*To further assist Owners, design teams, CxP teams, contractors, building/facility engineering, operations, and maintenance teams or staff, a number of supporting Cx technical guidelines have been developed or are under development. This particular guideline provides specific guidance on applying the Cx to HVAC&R systems in new buildings and facilities.*

*The Cx assumes that Owners, facility programmers, designers, contractors, and building engineering, operations, and maintenance (EOM) entities are fully accountable for the quality of their work. For example, the contractor is responsible for fully constructing, testing, and ensuring that their employees' work has provided the level of quality required by the agreement. The CxP then randomly samples the contractor's work to verify that it is achieving the OPR. If systemic issues of concern are identified, then the contractor is expected to recheck all of their work and correct any deficiencies. This quality-oriented Cx will provide improved quality and greater cost effectiveness compared to commissioning as currently practiced by many CxPs.*

*Ideally, the Cx begins at project inception (during the Predesign Phase) and continues for the life of a facility (through the Occupancy and Operations Phase). The Cx includes specific tasks to be conducted during each phase in order to verify that design, construction, and training meet the OPR. This guideline focuses upon the implementation of the Cx to HVAC&R systems and assemblies. It describes the specific tasks necessary to successfully implement the commissioning process for HVAC&R systems and assemblies.*

*In all of these guidelines, emphasis is placed upon documentation of the Owner's Project Requirements at the inception of a project and the proper transfer of this information from one party to the next throughout the life of a project. The commissioning process has been structured to coincide with the phases of a generic project with Predesign, Design, Construction, and Occupancy and Operations phases. Beginning the commissioning process at project inception will achieve the maximum benefits. If circumstances require Owners to adopt the commissioning process during the Design Phase, during the Construction Phase, or during the first year of the Occupancy and Operations Phase of a project, such later implementation must capture the information that would have been developed had the commissioning process begun at project inception or during Predesign Phase. This is required for successful Occupancy and Operations Phase documentation and continuous or ongoing commissioning of the HVAC&R systems and assemblies for the life of the facility.*

*Due to the integration and interdependency of most systems in a facility, a performance deficiency in one system can result in less than optimal performance by other systems. Although Guideline 1.1 focuses upon HVAC&R systems, a successful total building commissioning process will carefully validate interfaces and possible interferences between all building systems. Even when HVAC&R is the primary focus of the commissioning process, coordination among disciplines is essential for success.*

*Appendices are included in this guideline to assist in the implementation of the commissioning process to HVAC&R systems and assemblies. The appendices are based upon actual project experience, with details based upon current practice, and they illustrate application of the commissioning process to a variety of HVAC&R systems and equipment. The appendices should be viewed as examples of how to develop and define ongoing communications and planning tools: the Owner's Project Requirements, Basis of Design, and Commissioning Plan documents, and the verification, testing and training requirements.*

**Note:** *This document references annexes hosted on the ASHRAE website. Annexes are documents that constitute*

*a subordinate, informative part of more than one commissioning standard or guideline. They are maintained as unique documents and referenced by number in relevant commissioning standards and guidelines.*

*For example, the annex describing the issues and resolution log is used in multiple documents, since it applies in most applications of the Cx. It is therefore referenced by multiple standards and guidelines in the ASHRAE SSPC 300 family but exists as a single document for easier maintenance and better clarity.*

*All annexes in the ASHRAE SSPC 300 family can be found at [www.ashrae.org/SSPC300annexes](http://www.ashrae.org/SSPC300annexes).*

## **1 PURPOSE**

- 1.1** The purpose of this guideline is to provide specific technical detail that augments ASHRAE Guideline 0, *The Commissioning Process for New Buildings and New Systems*, and ANSI/ASHRAE/IES Standard 202, *Commissioning Process for New Buildings and New Systems*, specific to commissioning new heating, ventilating, air-conditioning, and refrigerating (HVAC&R).

## **2 SCOPE**

- 2.1** Provide specific commissioning content that expands on application of the commissioning process contained in ASHRAE Guideline 0 and ANSI/ASHRAE/IES Standard 202 for each project delivery phase from predesign through occupancy and operation for all types and sizes of HVAC&R systems. This includes requirements for:
- The system and assembly related content for inclusion in the Owner's Project Requirements
  - Defining the focus of design and submittal reviews, commissioning meetings, commissioning checklists execution process, and development of evaluation procedures to fully implement the commissioning process
  - Evaluation of the HVAC&R systems meeting the Owner's Project Requirements, Basis of Design, and Contract Documents through each phase of the project
  - Verification of maintainability and operability of commissioned HVAC&R systems
  - Documentation of issues, resolutions, and benefits of the process throughout the commissioning of HVAC&R systems
  - Systems Manual documentation
  - Training for operations and maintenance personnel and occupants
- 2.2** Establish a foundation that allows an Owner to implement an existing building commissioning process as established in ASHRAE Guideline 0.2, *Commissioning Process for Existing Systems and Assemblies*, and ASHRAE Guideline 1.2, *Technical Requirements for the Commissioning Process for Existing HVAC&R Systems and Assemblies*.

## **3 UTILIZATION**

- 3.1** This guideline is applicable to the installation of new HVAC&R systems and assemblies, including new construction, renovations, and modifications.
- 3.2** The application of this guideline depends upon the Owner's Project Requirements and how the project is designed, built, and operated. This guideline is supplemental to the commissioning process detailed in ASHRAE Guideline 0, and thus must be used in conjunction with Guideline 0. This guideline is not intended to be a stand-alone document.
- 3.3** This guideline describes specific details for the best practices to implement the Cx relative to new HVAC&R systems.

## **4 DEFINITIONS**

Definitions for Commissioning Process (Cx) terms can be found in ANSI/ASHRAE/IES Standard 202, *Commissioning Process for New Buildings and New Systems* and ASHRAE Guideline 0, *The Commissioning Process for New Buildings and New Systems*. No additional HVAC&R related terms are defined herein.

## **5 PREDESIGN PHASE**

**5.1 Introduction.** Information about the project is gathered, including:

- a. HVAC&R systems to be used or evaluated in the energy model
- b. Results of the energy model, if conducted
- c. High level or outline of the intended HVAC&R sequence of operation
- d. Definition of specific environmental conditions for specialized spaces
- e. Program requirements (e.g., facility interior conditions)
- f. Community context (e.g., noise from cooling towers)
- g. Codes and regulations (e.g., IMC, IECC, other code systems, EPA, etc.)
- h. Industry standards (e.g., ANSI/ASHRAE Standard 55, ANSI/ASHRAE Standard 62.1, ANSI/ASHRAE/IES Standard 90.1)
- i. Site and climate (e.g., outdoor air design conditions)
- j. Facility context and function (e.g., office, hospital, refrigerated warehouse)
- k. Facility system technology (e.g., heat recovery, cool storage, automation system)
- l. Building Automation Systems Controls (BACS) integration
- m. Sustainability (e.g., equipment energy efficiency, energy use, building certification program information)
- n. Resiliency
- o. HVAC&R costs
- p. HVAC&R equipment lead time
- q. Needs and capabilities of client (Owner, occupants, operators, and maintenance personnel)

Refer to SSPC 300 Informative Annex 04, “Owner’s Project Requirements” for additional items to include in the OPR document.

**5.2 Predesign Cx Activities**

**5.2.1 CxP Team Members.** In addition to those team members detailed in Guideline 0, the essential members of the CxP Team relative to HVAC&R systems during the Predesign Phase should include:

- a. Owner’s facilities engineer/manager
- b. Owner’s automatic controls and building automation technician
- c. Facility IT Network manager or technician
- d. Owner’s HVAC&R technician
- e. Architect
- f. Design professionals (e.g., HVAC&R)
- g. Electrical and other relevant consultants
- h. Controls and/or building automation specialist
- i. Environmental quality specialist

**5.2.2** If known or considered in the project, additional members of the CxP Team relative to HVAC&R systems during the Predesign Phase may include:

- a. Acoustic specialist
- b. Vibration specialist
- c. Measurement and verification specialist
- d. Information technology specialist
- e. Security specialist
- f. Life safety specialist
- g. Systems integrator

Refer to SSPC 300 Informative Annex 21, “Roles and Responsibilities” for details on roles and responsibilities of the above team members.

**5.2.3 Owner’s Project Requirements Document.** The Owner’s Project Requirements form the basic

requirements from which all design, construction, acceptance, and operation decisions are made. Where HVAC&R systems are concerned, the OPR should include the following:

- a. **Project Budget and Schedule:** A description of the Owner's approach to allocating resources for the HVAC&R systems. This entails a narrative of the relative importance of capital investment, life of systems, operating costs, maintenance costs, and use of the energy model for selection of the systems. Relative to the schedule, sufficient time must be allocated for design, construction, proper startup, testing, and tuning of HVAC&R systems.
- b. **Cx Scope:** A listing of HVAC&R components and systems that are the focus of the Cx and the level of effort to achieve the acceptance requirements of the Cx activities. Systems may include energy supply, heat generation, refrigeration, HVAC&R distribution, terminal and package units, HVAC&R instrumentation and controls, testing, adjusting, and balancing, and other special HVAC&R systems and equipment.
- c. **Project Documentation Requirements:** In addition to the commissioning documentation, a narrative of what documentation is required to properly install, start up, operate, troubleshoot, and maintain HVAC&R systems for the life of the facility. The narrative also includes the format of the documentation, either electronic or paper, and any specific features.
- d. **Owner Directives:** Many Owners have pre-defined directives on what systems, components, or operating conditions will be required. For example, this could be "all air systems, water systems, and control systems" or "only the central plant." It is critical, when directives are given, that the Owner's intent be understood. For example, if an Owner states that "only a specific manufacturer or type of system shall be used," it is important to understand that this directive relates to "the need to simplify maintenance due to the use of this manufacturer on their other 20 facilities."
- e. **Restrictions and Limitations:** Identify and document specific pre-existing or new restrictions and limitations on the HVAC&R systems. For example, it should be noted if a facility is being added to a campus loop that has an excess capacity of only 500 tons or if there are concerns from the local community about noise generation from a cooling tower.
- f. **Occupant/User Requirements:** Document the understanding of how the users (those with short-term occupancy of the facility, including visitors) define comfort (temperature, humidity, air movement, or non-mechanical control features of the facility's OPR requirements) and indoor air quality. Also, document the understanding of how the occupants (those with long-term occupancy of the facility) define comfort, indoor air quality, controllability, and interface with the operations and maintenance staff.
- g. **Space Use Requirements and Schedules:** Document the environmental needs required for animal, plant, or process operations. Document the initial schedules for occupancy/process, including numbers and hours for normal, holiday, and unique days, the occupant types and activity levels. As applicable, include environmental conditions, tolerances, and schedules for special space use applications (e.g., refrigerated warehouse, museum).
- h. **Future Space Use Requirements:** Owner defined considerations for future space and systems requirements, such as connections to adjacent buildings, potential space repurposing, etc.
- i. **Training Requirements for Owner's Personnel:** Document the current level of knowledge of the Owner's personnel and the intent to provide an adequate level of training on new HVAC&R technologies. This is important to enable design of HVAC&R systems within the Owner's current or future (additional training) capabilities. Refer to ASHRAE Guideline 1.3, *Application of the Commissioning Process to Building Operation and Maintenance Training*.
- j. **Warranty Requirements:** A listing of the requirements for warranties on the HVAC&R systems and components, including start of warranty, period, and conditions.
- k. **Benchmarking Requirements:** A listing of targets or benchmarks for future comparison and optimization of the HVAC&R systems. This includes facility design heating and cooling loads, HVAC&R equipment, systems and assemblies heating and cooling capacities, energy usage, efficiencies, performance information, and capabilities of the HVAC&R systems and components.
- l. **Statistical and Quality Assurance and Control Tools:** Document the sampling frequency to be used for the various systems and components during the Design and Construction Phase, including the need

for re-sampling or second review and the reasoning for the rates chosen. For example, “chillers and air handling units are sampled at 100% and unitary equipment is sampled at 20%.” Sampling percentages should be tailored for the type and size of facilities.

- m. **Operation and Maintenance Criteria:** A narrative of how the HVAC&R systems are to be operated and maintained, including how the operation and maintenance personnel approach resolution of problems (i.e., fix upon fail, manufacturer’s recommendations, or Owner-specified periodic frequencies), and the source (in-house or contracted) and expected level (current, new, additional) of manpower for the operations and maintenance staff, and known frequencies of maintenance items. Document the method for delivery of asset data.
- n. **Equipment and System Maintainability Expectations:** A summary of the assumptions for accessibility to HVAC&R systems and equipment (e.g., the maintenance space should be according to the manufacturer recommendations or x% greater). Further, special requirements for maintenance and access should be listed (e.g., gauges, test ports, permanent ladders, catwalks, and cranes).
- o. **Quality Requirements of Materials and Construction:** Describe the level of quality of the HVAC&R materials (new, recycled, and used), such as the use of galvanized, stainless steel, or ceramic cooling towers, including the durability and time expectancy between failures/replacement.
- p. **Energy Efficiency Goals:** These goals must always be defined by the OPR to provide adequate guidance and clear requirements for the design team and the operations team after occupancy. This should include the minimum acceptable energy efficiency level, which is typically defined in local codes, standards, or Owner’s established criteria.
- q. **Environmental Sustainability Goals:** Relative to the HVAC&R systems, document how the Owner defines efficiency and sustainability. This could be an energy usage per area, a percent value better than standard average usage (e.g., EnergyStar™ or school-district average), or a minimum value (code or Owner’s internal targets). In some projects, there may be specific requirements to obtain a sustainability rating, such as LEED™ or similar programs, or documenting the decarbonization to be achieved.
- r. **Adaptability:** Document the adaptability requirements for the HVAC&R systems to be modified, expanded, or relocated for future needs.
- s. **Systems Integration Requirements:** Document the need to integrate the HVAC&R systems with others, such as fire, life safety, envelope, daylighting control, and security that may be over and above code requirements.
- t. **Applicable Codes and Standards:** Detail the known HVAC&R codes and standards that will be followed for this project, including the year of the publication.
- u. **Health, Hygiene, and Indoor Environment:** Narratives for the HVAC&R systems should be developed for items such as:
  - Location of intakes: how to avoid introduction of pollutants from outdoor sources or exhaust air into the outdoor air intake.
  - Local exhaust: the use of local exhaust for such areas/items as kitchen, storage, laboratories, and copiers.
  - Materials in contact with air stream: the materials that the supply air stream will be in contact with and the potential for problems related to moisture and dirt accumulation.
  - Filtration: the level and type of filtration relative to the use of the space and the type of occupants.
  - Air exchange rates: the volume of outdoor air, including variations over time and the ability of the distribution system to deliver outdoor air to the occupied space. This should also include a discussion of the need for outdoor air to minimize the buildup of pollutants from material off-gassing in the space and/or generated by the intended usage of the conditioned space.
  - Chemical and pollutant production: the production of chemicals and pollutants by the HVAC&R systems due to maintenance or operation.
  - Transfer of outdoor pollutants: the transfer of pollutants from outside the building, such as dirt on the shoes of users and occupants, materials through the loading dock, or dust, dirt, and pollen through infiltration.
  - Evaporative cooling discharge.



- Installation of ultraviolet light, ionization, or air cleaner systems to the building air circulation systems or spaces for the mitigation of infectious aerosol distribution.
- v. **Acoustics:** Document the acoustic requirements for each space type (e.g., no noise production in a concert hall, or background noise production in an open office space). This should focus on the production of noise from the indoor and outdoor HVAC&R equipment and systems.
- w. **Vibration:** Document the vibration limitations generated by the indoor and outdoor HVAC&R equipment and systems of the facility.
- x. **Seismic:** Document the code seismic requirements and expectations for the HVAC&R equipment and systems.
- y. **Accessibility:** Document any unique requirements for placement of HVAC&R system components to meet the needs of occupants, such as location of sensors, switches, and emergency cut-offs.
- z. **Security (Physical and Cyber):** A narrative on the need for security of the HVAC&R systems relative to the use of the facility and potential threats to the facility and equipment.
- aa. **Functionality:** A narrative on the interface to the HVAC&R systems by the operations and maintenance personnel and by the occupants for the purpose of maintaining desired conditions. Define the requirements for the facility guide that is included in the Systems Manual.
- bb. **Aesthetics:** A narrative describing the relative location of the major HVAC&R systems and the exposure of HVAC&R components within the building (e.g., use of exposed ductwork or the type of diffusers) and outside the building (e.g., cooling towers and condensers).
- cc. **Constructability:** A narrative on any known restrictions that would limit the size or location of equipment or limit access for equipment for replacement. This could include how equipment is transported to the site (e.g., the only access road has a low bridge) or installed at the site (the use of high cranes or helicopters is prohibited).
- dd. **Communications (Operational):** A narrative on the use of one or multiple systems and accessibility to automatic controls and building automation systems from outside the facility. Discuss any requirements for cybersecurity (digital) for interior and exterior sources.
- ee. **Controls:** Controls for HVAC&R systems are the key to the design, installation, and operation of these systems. This should include intended building operating conditions and schedules as listed in the building facility guide. The OPR needs to clearly define the level of control and interoperability of systems. Control system performance needs to be defined during the Predesign Phase. In some facilities this may require a brief preliminary control predesign workshop. This is required for both the project cost budget and providing programming information for the design team and CxP Team during all phases of the project delivery.
- ff. **Integration of Other Building Systems with HVAC&R Systems:** A narrative that discusses the integration of HVAC&R controls systems with other building systems such as lighting, custodial, occupancy, security, vertical transportation, life safety, and others.
- gg. **Supplier Limitations:** Controls and refrigeration systems, including cool or warm storage, are sometimes limited to one or two manufacturers or vendors by market forces and/or by Owner. To achieve the benefit of these preselected vendors or manufacturers, they should have representation on the CxP Team at the Predesign phase of the project delivery. This will continue through Design, Construction, and Occupancy and Operations Phases.

**5.2.4 Scope and Budget.** Documentation for the scope and budget for the Cx for HVAC&R systems typically involves the following types of systems and equipment:

- a. Energy and water supply (including electricity; domestic water; oil supply; gas supply; coal supply; steam, hot water, and chilled water supply; solar or wind energy; geothermal, cogeneration [limited to HVAC&R systems], combined heat-cool plant, and similar systems)
- b. Heat generation (including boilers, furnaces, fuel-fired heaters, electric heaters, heat pumps, auxiliaries, and similar equipment)
- c. HVAC&R equipment and systems for human comfort (chillers, cooling towers, air handling units, heat pumps, etc.)

- d. Refrigeration equipment and systems for non-human comfort (including chillers, cooling towers, refrigerant compressors and condensers, refrigerated room equipment, refrigerated cases, heat pumps, and similar equipment)
- e. HVAC&R distribution (including air, water, steam distribution, special exhaust, heat recovery, condensate return, and similar systems)
- f. Terminal and package units (including unitary air-conditioning, air coils, humidifiers, dehumidifiers, terminal heat transfer units, energy recovery units, and similar equipment)
- g. HVAC&R instrumentation and controls (electric and electronic, pneumatic, self-powered systems, and sequence of operations, including system interlocks such as security, lighting, occupancy, etc.)
- h. Other special HVAC&R systems, equipment, and controls such as smoke control, plumbing, medical gas, air compressors, and other similar systems.

### 5.2.5 Cx Plan

- 5.2.5.1 General requirements for the Cx Plan are covered in ANSI/ASHRAE/IES Standard 202, ASHRAE Guideline 0, and SSPC 300 Informative Annex 05, “Commissioning Process Plan.”
- 5.2.5.2 **Milestones.** For general Cx milestones, refer to SSPC 300 Informative Annex 05, “Commissioning Process Plan.” In addition to milestones in Informative Annex 05, specific HVAC&R system milestones may include equipment factory testing and testing, adjusting, and balancing reports and verification.
- 5.2.5.3 **Roles and Responsibilities.** The roles and responsibilities of the CxP Team members relative to HVAC&R systems should be included in the Cx Plan. Refer to SSPC 300 Informative Annex 21, “Roles and Responsibilities” for additional information.
- 5.2.5.4 **Predesign Checklists.** Use the generic formats available at “SSPC 300 Examples/Other Supplementary Informative Materials” ([www.ashrae.org/SSPC300annexes](http://www.ashrae.org/SSPC300annexes)) to develop Predesign Phase Checklists. These generic formats are provided to assist with the development of predesign phase checklists. These checklists should be used to define expectations for each submittal of documentation during the Predesign Phase. In established Cx programs, Owners or project managers may have an established checklist for use by the CxP Team as they develop the OPR.
- 5.2.5.5 **Design Checklists.** Use the generic formats available at “SSPC 300 Examples/Other Supplementary Informative Materials” ([www.ashrae.org/SSPC300annexes](http://www.ashrae.org/SSPC300annexes)) to develop Design Phase Checklists. Specific design tasks required for HVAC&R systems and components should be developed by the CxP Team and the programming team during the development of the initial Cx Plan during the Predesign Phase. These tasks should include assemblies and systems that are essential for a successful HVAC&R installation. The tasks should define the expectations at each design submittal and will emphasize OPR, Basis of Design, and documentation expectations throughout the Design Phase.
- 5.2.5.6 **Construction Checklists.** The requirement for Construction Checklists should be included in the predesign documentation to define the project needs for the design team. Determine if checklists are in paper or electronic format, or in a web-based software format for contractor completion. Specific construction checklists required for HVAC&R systems and components, and supporting systems and assemblies, should be determined during the Design Phase.  
  
*Informative Note:* Example checklists for HVAC&R components, systems, and supporting assemblies can be found as “SSPC 300 Examples/Other Supplementary Informative Materials” ([www.ashrae.org/SSPC300annexes](http://www.ashrae.org/SSPC300annexes)).
- 5.2.5.7 **Communication Channels.** The communication process between the CxP Team and CxP, the HVAC&R and electrical design professionals, architect, Owner, occupants and users, facility engineering (which shall include operations and maintenance staff), general contractor, mechanical contractor, electrical contractor, and others as applicable should be defined. This process facilitates the review of predesign requirements, design requirements, the resolution of issues, and exchange of documentation. The designation of those involved may vary and participants may take on various names. For example, the Owner may be defined as the project manager, or the contractor may be defined as construction manager. The communication plan should include contact information for the CxP Team members and all other key project participants.



- 5.2.6 Issues Log Items.** Issues log items should be documented according to SSPC 300 Informative Annex 11, “Issues and Resolution Log” and ASHRAE Guideline 0, Section 5.2.5, “Establish Issues and Resolution Log Procedure.”
- 5.3 Acceptance Criteria.** See Guideline 0, Section 5.3, for predesign phase acceptance requirements. Additional information is provided in Guideline 0, Informative Appendix H, “Acceptance Plan.”
- 5.4 Predesign Phase Documentation.** See Guideline 0, Section 5.4, for predesign phase documentation requirements. Additional information is provided in SSPC 300 Informative Annex 01, “Commissioning Process Documentation Matrix.”
- 5.5 Predesign Phase Training Identification Requirements.** See Guideline 0, Section 5.5, “Predesign Training Identification Requirements,” for training identification requirements. Additional information is provided in ASHRAE Guideline 1.3, *Application of the Commissioning Process to Building Operation and Maintenance Training*.

## 6 DESIGN PHASE

### 6.1 Introduction

- 6.1.1** During the Design Phase of the project delivery process, the Owner’s Project Requirements are translated into construction documents. Initially, this translation starts with a document called the Basis of Design is created that clearly conveys the assumptions made in developing a design solution that fulfills the intent and criteria in the Owner’s Project Requirements document. Narrative descriptions of HVAC&R systems are developed and included in the Basis of Design, and the Cx Plan is expanded to include details of Construction Phase and Occupancy Phase activities relative to HVAC&R systems.
- 6.1.2** Design Phase Cx objectives relative to HVAC&R systems shall include all requirements of Guideline 0, Section 6.1, plus the following:
- a. Verify that the HVAC&R systems selected by the design team meet all the objectives and functional requirements listed in Section 5.2.2 of this guideline that are included in the OPR.
  - b. In addition, the following requirements are specific to the success of HVAC&R systems:
    1. Verify that systems and components are maintainable and accessible, especially since HVAC&R systems have higher and more ongoing operations and maintenance requirements than other building systems and assemblies.
    2. Review the construction documents and supplemental data to determine that the life cycle cost of HVAC&R systems have been optimized, in that the replacement frequency of building systems and assemblies has been minimized.
    3. Verify that the design of the building automation and energy management systems can achieve the control requirements and energy efficiency defined in the OPR and BoD.
    4. Verify that control systems requirements are clearly defined.
    5. Verify that sequence of operations and sequence of control are clear and well documented.
    6. Verify that indoor air quality requirements are analyzed and documented on the construction documents.
    7. Verify that the requirements of related HVAC&R support systems and assemblies are included in the design and that integration is adequately addressed.
    8. Verify that the design team develops adequate benchmarking of HVAC&R systems during occupancy for the Cx Team. These may be additions to Occupancy Phase benchmarks developed during Predesign, modifications of previous benchmarks, or recommendations to delete previous benchmarks if they do not relate to the final HVAC&R system design.
    9. Verify that the design team has adequately addressed noise, vibration, and seismic requirements.
- 6.1.3** Use quality-based sampling for verification of each HVAC&R activity or task determined to be related to the Owner’s Project Requirements in the design phase. SSPC 300 Informative Annex 02, “Quality Based Sampling Process,” provides procedures for sampling design phase activities and guidance on quality-based

sampling process procedures and sampling rates during the construction phase. These procedures should be addressed by the design team and included in the construction documents.

## **6.2 Design Phase Cx Activities**

### **6.2.1 Design Phase Cx Responsibilities**

**6.2.1.1** In addition to those detailed in Section 5.2.1, other members of the CxP Team relative to HVAC&R systems during the Design Phase may include, but are not limited to the following:

- a. Construction manager
- b. General contractor
- c. Design-build contractor
- d. Financial manager

**6.2.1.2** Responsibilities of the CxP Team during the Design Phase are defined in Guideline 0, Section 6.2.

### **6.2.2 Basis of Design Documentation**

**6.2.2.1** The Basis of Design for HVAC&R systems should include, but not necessarily be limited to, the following:

- a. A description of each system option considered, such as type of HVAC&R system, heat source, refrigeration systems, thermal storage, cogeneration, alternative energy sources, indoor air quality approaches, and interaction of the HVAC&R system with the building envelope, lighting, and other systems.
- b. A description of the building automation systems, including user access levels hierarchy, integrations, and capability of systems and sub-systems.
- c. The reasoning for the selection of the final HVAC&R system. This should be a short statement for each system (heating, cooling, fluid distribution, etc.) and include supporting information such as the requirements of codes/ standards, design criteria (e.g., energy performance, indoor environmental quality, reliability, maintainability, first- and life-cycle costs, preferred energy source), and Owner directives.
- d. Facility, system, and assembly performance assumptions.
- e. Assumptions for calculations/sizing, including diversity factors, safety factors, redundancy, space usage and occupancy (both proposed and potential), ventilation rates, plug loads, lighting loads, power density, glazing and shading device characteristics, thermal insulation and vapor transmission, envelope reflectivity, material densities, utility rates, pollutant sources, pressurization requirements.
- f. Analytical procedures and tools used during design, including manual and software (including version) analysis and simulation models (heat loss, cooling load, duct pressure, pipe sizing, energy usage, control strategies), and manufacturers' sizing services.
- g. Environmental conditions, including indoor and outdoor design conditions and air quality, interior pressure relationships, airflow velocity, and acoustic requirements.
- h. Current limitations such as financial, spatial, zoning, and site constraints.
- i. Reference make and model for equipment used as the basis of design.
- j. Operational assumptions, including facility and space usage, schedules (occupancy and operational), diversity, annual operation and maintenance budget, and personnel capabilities.
- k. Calculations, including the electronic inputs and outputs of modeling programs or copies of manual calculations to show the progression from assumption to calculation to the construction documents.
- l. Narrative system and assembly descriptions. These generally describe how the designer intends to meet the HVAC&R-related Owner's Project Requirements and how the OPR are updated and made more detailed as the design progresses. The narrative should describe general systems and equipment (e.g., chillers, boilers, air-handlers, air and water distribution) and an outline sequence of operations. SSPC 300 Informative Annex 06, "Basis of Design," presents a sample HVAC&R system narrative and description.

- m. Codes, standards, guidelines, regulations, and other references that influenced the design of HVAC&R systems.
- n. Owner guidelines and directives that influenced the design of HVAC&R systems.
- o. Achievement of Owner's Project Requirements, including a specific listing of how each Owner's Project Requirements is addressed in the construction documents.

### **6.2.3 Updating of Cx Plan**

**6.2.3.1** General requirements for updating the Cx Plan during the Design Phase are covered in Guideline 0, Section 6.2.3. The Cx Plan shall be updated to reflect changes in the Owner's Project Requirements and include additional information developed during the Design Phase.

**6.2.3.2** During the Design Phase, the following shall be added to or updated in the Cx Plan relative to HVAC&R systems:

- a. Systems and assemblies to be verified and tested. These typically include, but are not limited to, the following:
  - 1. Energy supply
  - 2. Safety-related systems, including alarms, fire, and power failure
  - 3. Heat generation
  - 4. HVAC
  - 5. Refrigeration
  - 6. HVAC&R distribution
  - 7. Terminal and package units
  - 8. HVAC&R instrumentation and controls
  - 9. Other special HVAC&R systems and equipment
- b. Identify HVAC&R-related milestone Cx activities for the Construction Phase and for the Occupancy Phase. The activities should identify anticipated duration and critical times for witnessing testing activities, for accessing HVAC&R systems and equipment, for accessibility for maintenance and verification, for completion of Construction Checklists, and for activities relative to substantial completion/project closeout.

#### **6.2.3.3 Milestones**

**6.2.3.3.1** During the Design Phase, it is critical to update and document key milestones relative to the HVAC&R systems. These milestones include:

- a. Predesign meeting (as a completed activity)
- b. Design review (multiple), including the Basis of Design
- c. Updated Cx Plan
- d. Construction pre-bid meeting
- e. Pre-construction meeting
- f. Cx meetings
- g. Submittal (including manufacturers' operations and maintenance documentation) review
- h. Systems Manual: a specific time for completion of this activity should be established based upon project complexity
- i. Submission of automatic control and building automation controls software - a specific time for completion of this activity after submittal acceptance should be established based upon project complexity
- j. Training program implementation plan
- k. Construction Checklist completion and tracking
- l. Equipment installation review
- m. Equipment startup
- n. Testing procedure development (update Cx Plan)

- o. Initial automatic controls and building automation system acceptance
- p. Testing, adjusting, and balancing report and verification
- q. Final automatic controls and building automation system acceptance
- r. HVAC&R system functional testing
- s. Final Systems Manual submission
- t. Operator training
- u. Turnover of systems/HVAC&R systems acceptance, including the start of warranties
- v. Draft Cx Report
- w. CxP site visits during first year of operation
- x. Seasonal testing
- y. Lessons-learned meeting
- z. Final Cx Report

#### **6.2.4 Cx Requirements in the Construction Documents**

**6.2.4.1** Integrate specific commissioning documentation requirements (including use of Construction Checklists) into the relevant HVAC&R specification sections (and others as appropriate), with appropriate cross-references.

**6.2.4.2** Integrate HVAC&R Cx activities into the relevant HVAC&R specification divisions as required. A guide specification section template for HVAC&R Cx requirements is provided in SSPC 300 Informative Annex 07, "Commissioning Specifications."

**6.2.5 Construction Checklists.** SSPC 300 Examples/Other Supplementary Informative Materials contains sample formats for typical HVAC&R Construction Checklists. See Section 7.2 for further information. General requirements for Construction Checklists are presented in Guideline 0, Section 6.2.

#### **6.2.6 Systems Manual**

**6.2.6.1** The format of the HVAC&R Systems Manual shall be clearly stated in the Construction documents. See Guideline 1.4, *Preparing Systems Manuals for Facilities*, for a sample format and suggested contents for a typical HVAC&R system, in addition to the list below.

**6.2.6.2** The sections in the Systems Manual are developed for each major HVAC&R system (typically following the CSI Master Format numbering system); these usually include (but are not limited to):

- a. Energy supply (including the oil supply; gas supply; coal supply; steam, hot water, chilled water supply solar or wind energy, and similar systems)
- b. Heat generation (including boilers, furnaces, fuel-fired heaters, auxiliaries, heat pumps, and similar equipment)
- c. HVAC for human comfort (chillers, cooling towers, air handling units, VAVs, heat pumps, etc.)
- d. Refrigeration (including refrigerant compressors and air-cooled condensers, cold storage room equipment, cold storage cases, and similar equipment)
- e. HVAC&R distribution (including air, water, steam distribution; special exhaust; and similar systems)
- f. Terminal and package units (including unitary air-conditioning, air coils, humidifiers, dehumidifiers, terminal heat transfer units, energy recovery units, and similar equipment)
- g. HVAC&R instrumentation and controls (including electric and electronic, pneumatic, self-powered systems, and the sequence of operations)
- h. Other special HVAC&R systems, equipment, and controls

**6.2.6.3** The requirements for contractor-supplied information for the HVAC&R Systems Manual shall be clearly stated in the Construction documents.

#### **6.2.7 Training Requirements**

**6.2.7.1** General requirements for development of training requirements during the Design Phase outlined in ASHRAE Guideline 0, Section 6.2, and ASHRAE Guideline 1.3, provide HVAC&R-specific

recommendations for the training program and Training Manual. In general, HVAC&R training will address a range of knowledge sets and should be provided through a variety of formats tailored to the needs and capabilities of the Owner's operating personnel as expressed in the Owner's Project Requirements. HVAC&R training should cover overall systems as well as individual equipment.

- 6.2.7.2 Training on overall HVAC&R systems concepts and intents should be done in a classroom setting and actively involve the HVAC&R design professionals. Topics should include the HVAC&R Basis of Design, HVAC&R systems operation (normal, emergency, limitations, cold start), and similar big-picture issues.
- 6.2.7.3 Training on specific HVAC&R equipment should be provided in appropriate forms (including classroom, field, and factory training settings as warranted). Major equipment (chillers, boilers, controls) training should address preventive maintenance, operations, and troubleshooting. The type and level of training should relate to the Owner's approach to operations and maintenance (in-house, contract, or a combination) described in the Owner's Project Requirements. Training on secondary equipment will vary from component to component and should also relate to the Owner's O&M approach.
- 6.2.7.4 Training should occur throughout the Construction Phase and into the Owner Occupancy Phase as appropriate to the construction schedule, equipment types, and Owner's needs.
- 6.2.7.5 Training requirements and responsibilities shall be clearly stated in the construction documents and professional services agreements. The design professionals, contractors, control contractor/vendor, manufacturers, other vendors, and CxP will be involved in training on HVAC&R systems. The scope and training expectations shall be clearly stated in the specifications and other contract agreements, especially the coordination role with the contractor. There should be consideration for manufacturer's training on controls systems, software, chillers, and for how systems have been integrated (fire/life safety integration with the HVAC&R system). Training should involve operator, maintenance, repair, and ongoing training for HVAC&R systems. Additional guidance on training is provided in ASHRAE Guideline 0, Section 6.2, and ASHRAE Guideline 1.3.

## 6.2.8 Design Review of Construction Documents

- 6.2.8.1 The process for accomplishing design reviews for the purpose of verifying achievement of the Owner's Project Requirements is described in ASHRAE Guideline 0, Section 6.2, including recommended sampling rates for the commissioning process verification activities described in Section 6.2.8. Specific to HVAC&R systems, the following guidance is provided for the four-step review process in ASHRAE Guideline 0, Section 6.2.
  - 6.2.8.1.1 **General Quality Review.** The general quality review for HVAC&R systems should focus on completeness, organization, and readability of drawings and specifications with attention to details, schedules, controls, ductwork, piping, equipment rooms, phasing, legends, and equipment identification.
  - 6.2.8.1.2 **Coordination Review.** Key system elements and random samples (10-20%) of other portions of the HVAC&R systems are reviewed to evaluate the coordination accomplished within and among disciplines. This includes reviewing for interfaces among disciplines (e.g., whether ductwork will fit above ceilings, whether there is electrical power to equipment, whether condensate drainage is provided) and checking the design against the Owner's Project Requirements (e.g., the OPR requires that all equipment shall have sufficient space for maintenance, commissioning, and control adjustment; or that other systems do not interfere with access to the HVAC&R systems).
  - 6.2.8.1.3 **HVAC&R System-Specific Review.** Within the areas selected for review, verify that the design complies with the Owner's Project Requirements. Specific issues to consider include determining whether equipment tags match schedules, whether air and water flows match schedules, whether schedules match load calculations (capacities, heads, pressures), and whether loads and calculations are based upon stated assumptions?
  - 6.2.8.1.4 **HVAC&R Specification Review.** A review of the specifications shall be performed to determine completeness, applicability to the project, and compliance with the Owner's Project Requirements. The CxP Team will only review a sample of the specifications, as determined by the scope of the commissioning services, to verify the design includes a quality process and are meeting the OPR. Items checked include applicability of the section to the project, Cx requirements, submittal

requirements, applicability of equipment to the project, training requirements, coordination with other sections, and coordination with the drawings.

- 6.3 Design Phase Acceptance Requirements.** Refer to ASHRAE Guideline 0, Section 6.3, for Design Phase acceptance requirements.
- 6.4 Design Phase Documentation Requirements.** Refer to ASHRAE Guideline 0, Section 6.4, for Design Phase documentation requirements.
- 6.5 Design Phase Training Identification Requirements.** Refer to ASHRAE Guideline 0, Section 6.5 for Design Phase training requirements.

## 7 CONSTRUCTION PHASE

**7.1 Introduction.** Cx activities to be performed by the various members of the CxP Team during the Construction Phase are described in ASHRAE Guideline 0, Section 7. Additional information on specific activities relative to HVAC&R systems is presented in this section and includes:

- a. Developing or updating of the construction checklists prepared during the design phase to reflect the specific equipment/materials approved by the design professionals. See “SSPC 300 Examples/Other Supplementary Informative Materials” ([www.ashrae.org/SSPC300annexes](http://www.ashrae.org/SSPC300annexes)) for representative examples of HVAC&R Construction Checklists.
- b. Developing or updating functional test procedures to reflect the specific equipment/systems approved by the design professionals. See Informative Appendix U, “Test Procedures and Data Forms,” for representative examples of HVAC&R test procedures.
- c. Verifying the integration of HVAC&R controls and system components with other building systems, such as fire and life systems, electrical power systems, lighting control systems, active envelope systems, etc.
- d. Verifying the results of the testing, adjusting and balancing (TAB) work for HVAC&R air and water systems.
- e. Verifying the results of the pressure testing work of HVAC&R air and water systems.
- f. Scheduling of the seasonal and occupancy-dependent testing.
- g. Verifying specific elements are put in place for ongoing Cx and measurement and verification programs as approved by the design professionals and OPR.

### 7.2 Construction Phase Cx Activities

#### 7.2.1 Carry Out Construction Phase Cx Responsibilities

**7.2.1.1** Essential HVAC&R CxP Team members, in addition to those listed in ASHRAE Guideline 0 (Section 7.2), include the mechanical contractor, mechanical equipment suppliers and authorized vendors, sheet metal and piping contractors, building automation and controls contractor, systems integrator(s), TAB contractor, water quality specialists, and any other HVAC&R systems related specialists.

**7.2.1.2** Responsibilities of the CxP Team include the following activities that are specific to HVAC&R. See SSPC 300 Informative Annex 09, “Submittal Review,” for additional information.

- a. Review the HVAC&R submittals (shop drawings, coordination drawings, installation and startup instructions, operations and maintenance instructions) for compliance with the Owner’s Project Requirements and design documents. This includes controls, TAB, duct and pipe layout, equipment room layout and accessibility for commissioning and maintenance, maintenance-troubleshooting parts lists requirements, ceiling space coordination, and underfloor coordination.
- b. In addition to HVAC&R submittals, the HVAC&R-focused CxP Team needs to review related submittals to verify that lighting and power loads in spaces and building envelope thermal assemblies meet the OPR for cooling, heating, ventilating, and refrigerating loads.
- c. Other related systems with submittals that should be reviewed to verify that they meet the OPR include smoke evacuation systems, any specialty equipment and systems requiring building’s HVAC services, including but not limited to, fume hoods, kitchen hoods, and vacuum pumps. In addition, review the plumbing supply and drains, and electric power equipment and supply for



HVAC&R systems.

### **7.2.2 Hold Pre-Bid Conference**

**7.2.2.1** Refer to ASHRAE Guideline 0, Sections 5.2 and 7.2, for general pre-bid conference orientation. The pre-bid meeting is the opportunity to provide all bidders with an overview of HVAC&R-unique requirements and the scope of Cx activities that will occur during construction and the projected levels of effort. It is very important that bidders understand their roles in the Cx. This is also an opportune time to discuss the reason for including the Owner's Project Requirements and Basis of Design in the bidding documents (as information only and not contract requirements) and emphasize that this information is for the benefit of building operations and ongoing Cx after construction is completed. Bidder questions regarding the Cx requirements should be addressed with appropriate responses to all bidding contractors.

**7.2.3 Coordinate Owner Representatives' Participation in the Cx.** Refer to Guideline 0, Section 7.2, for a general description. The HVAC&R construction Cx may include, but is not limited to, the following participants:

- a. Facility engineers and operators
- b. HVAC personnel
- c. Refrigeration personnel
- d. Heating personnel
- e. Building automation controls personnel
- f. Electrical personnel
- g. Craft laborers or workers
- h. Boiler and chiller plant operators
- i. Facility IT personnel for operational communication and cybersecurity

**7.2.4 Update Owner's Project Requirements.** Refer to Guideline 0, Section 7.2, for general guidance. If any proposed HVAC&R changes that are at variance with the Owner's Project Requirements are approved by the design professionals and Owner during the Construction Phase of the project, then the OPR (and Basis of Design) must be revised and approved. This provides for continuous updating of the OPR (and BoD) to reflect the constructed project.

### **7.2.5 Update the Cx Plan**

**7.2.5.1** Refer to Guideline 0, Section 7.2.

**7.2.5.2** Specialists with knowledge of specific systems and equipment may be utilized as resources for the HVAC&R CxP Team and listed in the Cx Plan, with roles and responsibilities. The HVAC&R Cx activities may include specialists in the following areas:

- a. High pressure boiler
- b. Acoustics and vibration
- c. Laboratory equipment and controls
- d. Air filtration/air quality
- e. Water treatment
- f. Systems integration
- g. Computerized maintenance management systems
- h. Others as required

### **7.2.6 Conduct Preconstruction Cx Meeting**

**7.2.6.1** Refer to Guideline 0, Section 7.2.

**7.2.6.2** During the preconstruction meeting, the OPR, BoD, and unique contract document requirements for HVAC&R systems are reviewed. In addition, the specific roles and responsibilities of the contractors relative to the Cx activities are reviewed.

- a. Special issues relative to sequencing and early installation of HVAC&R equipment located in limited access areas (such as equipment to be installed in lower levels of a building) should be

- discussed
- b. Coordination of TAB and controls
- c. Coordination of functional testing of equipment and systems with manufacturers, installers, and controls contractor
- d. Prerequisite items for completion of HVAC&R systems and readiness for Cx testing
- e. Expectations of roles and responsibilities for trade partners to support the HVAC&R Cx activities
- f. How issues and deficiencies are resolved. Conditions under which the test is considered a failure and when a retest of the HVAC&R system is required.
- g. When seasonal, deferred, or postoccupancy testing is required and conducted.

### **7.2.7 Verify Submittals**

- 7.2.7.1** Refer to Guideline 0, Section 7.2, and Informative Appendix M, “Construction Checklists,” for general procedures and sampling strategies.
- 7.2.7.2** Coordination drawings and/or coordinated BIM model should be reviewed to verify that the following requirements have been met:
  - a. Mechanical and electrical equipment spaces show structural elements, equipment, piping, ductwork, and conduit.
  - b. Ceiling space coordination drawings show a consistent layering for structural elements, ceiling grid, access doors and panels, fire and smoke dampers, lighting, piping, ductwork, conduit, and control elements.
  - c. Vertical shaft coordination drawings for piping and ductwork show structural elements, equipment, piping, ductwork, and conduit.
  - d. Specified clearances are shown for maintenance and operation procedures appropriate to the accepted make and model of HVAC&R equipment.
  - e. Coordination drawings demonstrate adequate space for maintenance access and installation and identify spaces reserved for maintenance and operation procedures.
  - f. Spacing of equipment reflects actual equipment dimensions, including support hardware, fittings, and insulation.
  - g. Elevations in congested areas are provided to identify any potential interferences.
- 7.2.7.3 Equipment Submittals.** Equipment submittals should be obtained for use by the CxP. When reviewed and approved by the Project Team, equipment submittals should be used in developing the checklists and test procedures.
- 7.2.7.4** Submittal of the Building Automation System (BAS) controls for HVAC&R should include review of system architecture, sequences of operation, control logic diagrams, points list, cybersecurity implementation and sample control graphics screens.
- 7.2.7.5** The training-program submittals review includes the schedule, syllabus, evaluation forms, qualifications of the trainer, any video or other material that will be used, any proposed demonstration training, and recording or documentation of the training for future use and inclusion in the Systems Manual (refer to ASHRAE Guideline 1.4).
- 7.2.7.6** Review the TAB agency submittal to verify it includes the following items:
  - a. Specified qualifications and certifications of parties performing TAB work, including experience of field technicians
  - b. Protocol for review of design documents, shop drawings, and installed work for features that adversely affect or preclude proper TAB, including site inspection procedures preparatory to balancing
  - c. Protocol for using BAS for TAB
  - d. Field checkout and deficiency forms and logs
  - e. Final test report forms to be used
  - f. Procedure for notations and markings to be made on the duct and piping drawings for TAB

- operations
- 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, and test instrument types to be used for the measurements. This will frequently be included in the test forms discussed in requirement (e) above
  - h. Identification of measuring instruments to be used by type, manufacturer, model, serial number, and their most recent calibration date
  - i. Proposed selection of points for sound measurements
  - j. Details of any TAB work to be done in phases (by floor, for example), or of areas to be built out later
  - k. Details regarding specified deferred or seasonal TAB work
  - l. Procedures to measure and adjust required building and room pressure differentials
  - m. Plan for periodic submittals of field technician logs of discrepancies, deficient or uncompleted work by others, contract interpretation requests, and lists of completed tests (scope and frequency)
  - n. Plan for formal progress reports (scope and frequency)

**7.2.8 Schedule Construction Phase Cx Activities.** In addition to the general requirements in Guideline 0, Section 7.2, the following Cx activities and milestones for HVAC&R systems should be scheduled and coordinated with the construction schedule:

- a. Submittal reviews, including, but not limited to, equipment, coordination drawings, control interface wiring diagrams
- b. HVAC equipment installation and startups
- c. Refrigeration equipment installation and startups
- d. Leak testing of piping and ductwork components and systems
- e. Flushing and cleaning of piping and ductwork systems
- f. TAB of air and hydronic systems
- g. Site utilities testing
- h. BAS control system testing
- i. Testing of HVAC&R components and systems
- j. Integrated testing of HVAC&R systems with other building systems

### **7.2.9 Develop Functional (Cx) Test Procedures**

**7.2.9.1** In addition to the general Cx test procedure requirements in Guideline 0, Section 7.2, the following apply to HVAC test procedures.

**7.2.9.2** List of test procedures and data forms to verify conformance with Basis of Design and achievement of Owner's Project Requirements.

- a. Each project requires creation of Cx test procedures unique to that project. Therefore, the following discussion is intended to convey the thought process used to create a Cx test procedure. The list of test procedures and the sample test procedures and data forms in "SSPC 300 Examples/Other Supplementary Informative Materials" ([www.ashrae.org/SSPC300annexes](http://www.ashrae.org/SSPC300annexes)).
- b. The objective of these procedures is the verification that OPR have been achieved through a full range of control, loads, and modes that may be experienced during operation of the HVAC&R system. The focus is on the facility and system level, which is made up of the equipment, components, and assemblies verified using the Construction Checklists throughout construction. In addition, this may include tests to verify that the basis of design assumptions are met by individual components or systems required in achieving the OPR. For example, it should be verified that the cooling tower, chiller, pumps, valves, coils, fans, terminal units, and room air diffusers all perform together as a system to maintain space comfort and indoor air quality during morning occupancy (cooling east facade and heating west facade), peak cooling, peak wet-bulb, and late afternoon (neutral east facade and cooling west facade) conditions.

- c. The first step in developing a Cx test procedure is to determine which OPR items require a test procedure for verification. In order to accomplish this, the CxP Team needs to determine which components, assemblies, or systems contribute to a specific Owner's project requirement. Some tests may verify more than one project requirement. Consideration should be given to including logical groups of Owner's project requirements (involving the same equipment or assemblies) in a single procedure but expanding the scope of a test beyond what is manageable should be avoided.
- d. The second step in developing a Cx test procedure is to identify the key points of evaluation for each test. For example, to verify maintenance of comfort, the following operating conditions would be evaluated:
  - 1. East cooling/west heating,
  - 2. Peak load design conditions (minimum diversity),
  - 3. East heating/west cooling,
  - 4. Peak wet-bulb condition.
- e. The third step in developing a Cx test procedure is to identify what information must be documented to show OPR achievement (refer to Section 7.2.10 of this guideline).
  - 1. For an assembly, such as a cooling tower, verification of the ability of the assembly to control a variable (e.g., maintain leaving water temperature setpoints) under a wide range of load conditions is required.
  - 2. For a system, such as a chilled water system, verify the ability of the system to respond correctly to loads (cooling or heating loads within a space, or based upon outdoor temperature) under various modes of operation.
  - 3. For interactions of HVAC systems with other HVAC systems or non-HVAC systems, verify communications and responses between the systems, and verify that the required effect is delivered (e.g., daylighting, smoke control).

#### **7.2.9.3** Sequencing of the performance of Cx each test:

- a. Final completion of HVAC&R construction checklists. For components, the last section of their Construction Checklist is typically a start-up or TAB section, which is accomplished after the component is fully installed. The test will be scheduled after the Construction Checklist is completed and verified. The test may have a separate test form or an optional additional section on the checklist, or it may have a short list on the checklist with a more extensive report where a large amount of data is collected. Appropriate verification of the Construction Checklists should be accomplished by the CxP, prior to scheduling the test.
- b. The following should be accomplished prior to the start of any commissioning process OPR tests:
  - 1. Verify control system operation after TAB verification.
  - 2. Verify functionality and compliance with intent for each individual sequence module in the sequences of operation.
  - 3. Verify proper operation of all control strategies, energy efficiency, and self-diagnostics features by stepping through each sequence and documenting equipment and system performance. Test every step in every written sequence—and other significant modes, sequences, and operational features not mentioned in written sequences—including startup, normal operation, shutdown, scheduled on and off, unoccupied and manual modes, safeties, alarms, overrides, lockouts, and power failure and recovery.
  - 4. Verify all alarm and high- and low-limit functions and messages generated on all points with alarm settings.
  - 5. Verify integrated performance of all components and control system components, including all interlocks and interactions with other equipment and systems.
  - 6. Verify shutdown and restart capabilities both for scheduled and unscheduled events (e.g., high pressure shutdown and normal scheduled start/stop).

7. Verify proper sequencing of heat transfer elements as required to prevent inappropriate simultaneous heating and cooling.
  8. Verify sequencing of multiple stages or sources of heat transfer, refrigeration, and heat generation element capacities.
  9. Verify control system stability and tuning by upsetting various control loops under different load conditions and observing the system response.
  10. When applicable, demonstrate a full cycle from off to on and no load to full load and then to no load and off.
  11. Verify time-of-day schedules and set points.
  12. Verify all energy-saving control strategies.
  13. Verify that control system graphics are representative of the systems and that all points and control elements are in the same location on the graphic as they are in the field.
  14. Verify operator control of all control system points, including proper access level as agreed to during the controls integration meetings.
- c. System specific tests. Verify that all component construction checklists and tests have been accomplished and deficiencies corrected prior to performing the system test. If the deficiency cannot be corrected, then an agreement must be reached on how results of the system test expectations and procedures will be modified for acceptance.
  - d. Intersystem tests. Verify that all HVAC&R component construction checklists and tests have been accomplished. In addition, verify that related systems components are working according to the specifications. If the components in the related systems are included in the Cx Plan, then construction checklists can be used to verify the intersystem tests.

**7.2.9.4** Step-by-step instructions for tests specific to HVAC&R systems include, but are not limited to:

- a. Verify operation of systems and components under low, normal, and high load conditions.
- b. Verify operation of systems and components during combinations of environmental and equipment interaction conditions that could reasonably exist.
- c. When applicable, demonstrate a full cycle from off to on and no load to full load and then to no load and off.

**7.2.9.5** Some examples of HVAC&R OPR Cx test verification objectives include:

- a. Comfort
- b. Indoor air quality
- c. Environmental goals
- d. Energy efficiency
- e. Support of other systems

**7.2.10 Develop Test Data Records**

**7.2.10.1** In addition to the items listed in ASHRAE Guideline 0, the following HVAC&R-related items should be included:

- a. Trend logs,
- b. Detailed responses to input changes, including response times if they are critical,
- c. Flows, temperatures, pressures, volumes, capacities, and other required data to confirm equipment and system capabilities,
- d. State of each component that could affect the Owner's Project Requirements (e.g., the state of the cooling tower, chiller, pumps, valves, fans, VFD's, terminal units, the space, and the outdoors when accomplishing a comfort test).

**7.2.11 Conduct CxP Team Meetings**

**7.2.11.1** CxP Team meetings may be required to specifically address HVAC&R-related issues. These meeting

should be organized and conducted in accordance with the guidelines established in ASHRAE Guideline 0. The meetings may or may not be conducted within a regularly scheduled Cx meeting. Attendees should include all parties and disciplines affected by the subjects under consideration. Such meetings might include:

- a. HVAC&R installation, startup, and Cx testing
- b. Equipment coordination within the HVAC&R discipline
- c. Review of construction checklist procedures
- d. Review of Owner's Project Requirements verification test procedures
- e. Control system implementation and coordination
- f. Pre-TAB preparation
- g. Review of TAB report
- h. Review of Issues Log

#### **7.2.11.2 Special Coordination Meetings**

- a. Verification Protocol and Construction Checklist meetings: Essential HVAC&R CxP Team members, in addition to those listed in ASHRAE Guideline 0, include the mechanical contractor, mechanical equipment suppliers, sheet metal and piping subcontractors, environmental controls and systems integrator(s), TAB contractor, water quality specialists, and any other specialists required to address a specific verification protocol and checklist procedure.
- b. CxP Team Meetings: Convene special CxP Team meeting(s) as required to address the control system and the TAB activities.
  1. Controls Meeting: Convene a meeting to review the sequencing, coordination with other controls (for example fire and life safety, security, lighting) and completion of control system installation activities. Attendees include the CxP, mechanical design professional, Owner's operation and maintenance representative, general contractor and/or construction manager, mechanical contractor, control contractor, TAB contractor, electrical contractor, and fire alarm contractor. The following items are addressed during this meeting.
    - a) A meeting early during construction may be held with the mechanical designer, CxP, controls contractor, and Owner to review and discuss controls issues prior to control programming and the controls formal submittal. Items that may be covered include system architecture, control drawing format and content, sequences of operation details and logic, control database, point naming convention, alarms, graphic screens, location of critical sensors, and other coordination issues.
    - b) Control package submittal content requirements and scheduling, including products, sequence of control, control logic diagram, and control software.
    - c) Ongoing point-to-point control system verification requirements as well as other information on the Construction Checklists.
    - d) Resolution procedures to be followed.
    - e) Documentation submittal requirements and timing.
    - f) Involvement in Cx test completion at end of the project.
  2. TAB meeting: convene a meeting to review the sequencing, coordination with other controls (for example fire and life safety, security, lighting) and completion of control system installation activities. Attendees include the CxP, mechanical design professional, Owner's operation and maintenance representative, general contractor and/or construction manager, mechanical contractor, control contractor, TAB contractor, and electrical contractor. The following items are addressed during this meeting.
    - a) Sequencing of events (equipment Construction Checklist completion, control system Construction Checklist completion, system start-up, TAB, TAB verification, Cx testing completion).
    - b) TAB contractor test report forms and submission procedures.



- c) Review of Cx checklists, submission procedures, and frequency.
- d) Identification, documentation, and resolution of issues identified by TAB contractor.
- e) Interface between TAB contractor, controls contractor, mechanical contractor, and electrical contractor.

#### **7.2.12 Schedule Periodic Site Visits to Verify Accomplishment of the Owner's Project Requirements**

**7.2.12.1** Coordination of the timing of these HVAC&R system visits should consider construction progress. Examples of specific milestones that may trigger site visits include the following:

- a. Sub-grade piping installation before it is covered
- b. Delivery of major pieces of equipment
- c. Completion of rough-in before walls are covered
- d. Completion of above-ceiling equipment before ceilings are installed

**7.2.12.2** SSPC 300 Informative Annex 02, "Quality Based Sampling Process," contains information regarding application of quality-based random sampling to HVAC&R systems site verifications.

#### **7.2.13 Conduct Tests**

**7.2.13.1** Participants required for the test may include, in addition to the participants listed in Guideline 0, the following contractors:

- a. Sheet metal contractor
- b. Mechanical piping contractor
- c. Controls/BMS contractor
- d. Contractor(s) responsible for air and water test and balancing
- e. Mechanical contractor
- f. Electrical contractor
- g. Other contractors and specialists with knowledge of specific systems and equipment that interface with the HVAC&R systems, such as high-pressure boiler, fume hood, water treatment, power quality, radio frequency interference, and systems integrators

**7.2.13.2 Monitoring.** Monitoring is a method of testing, either as a stand-alone method or to augment manual testing. Features and functions not able to be fully or readily verified through manual tests may be verified through BAS trend logs, including (but not limited to): space and discharge air temperature control, relative humidity control (if required), heat pump water loop temperature, outdoor air control, optimum start, cycling, and staging control, and time of day scheduling. Verifying that actuator control loops are not hunting may require a one- to two-minute sampling frequency. Other data points may not require as short a sampling rate. Prior to utilizing the BAS for verification, calibrations of the BAS inputs must be completed and values showing on the workstation screen verified.

**7.2.13.3 Deferred Tests.** Execution of some HVAC&R tests may be deferred until appropriate conditions, such as full-load building occupancy, design functional activities, or design weather conditions are present. Examples of deferred tests include humidity control, heating and cooling equipment capacity verification, carbon dioxide concentration-based evaluation of ventilation effectiveness. Schedules for these tests should be established.

**7.2.13.4** SSPC 300 Examples/Other Supplementary Informative Materials provides examples of HVAC&R construction checklists.

**7.2.13.5** Informative Appendix U, "Test Procedures and Data Forms," provides an example of a "comfort" OPR Cx test procedure and data forms. A sample Issues and Resolution Log is included.

**7.2.14 Verify Training.** See ASHRAE Guideline 0 for general requirements. Adjust training verification criteria to reflect HVAC&R installation if necessary. This may include review of the video recordings of the sessions as well as other advanced documentation methods. This may also include building computerized documentation systems for operations and maintenance of HVAC&R systems and components. This includes staged recordings and manufacturers' training materials.

**7.2.15 Complete Construction Phase Cx Report.** See ASHRAE Guideline 0, Section 7.2, for requirements.

**7.2.16 Verify Systems Manuals Update.** See ASHRAE Guideline 0, Section 7.2, for requirements.

**7.2.17 Verify Updates to Basis of Design.** See ASHRAE Guideline 0, Section 7.2, for requirements.

**7.3 Construction Phase Acceptance Requirements.** See ASHRAE Guideline 0, Section 7.3, for requirements.

**7.4 Construction Phase Documentation Requirements.** See ASHRAE Guideline 0, Section 7.4, for requirements.

**7.5 Construction Phase Training Requirements.** See ASHRAE Guideline 0, Section 7.5, for requirements.

## **8 OCCUPANCY AND OPERATIONS PHASE**

**8.1 Introduction.** Cx activities described in this section to be performed by the various members of the CxP Team during the Occupancy and Operations Phase are generally described in ASHRAE Guideline 0, Section 8. The following information focuses on specific activities relative to HVAC&R systems:

- a. Facilitating the identification, troubleshooting, and resolution of HVAC&R system issues throughout at least the first year of occupancy, including the involvement of the associated contractor and/or design professional when required by construction documents and applicable codes.
- b. Verifying ongoing upkeep of project documentation in the Systems Manual, especially the Owner's Project Requirements, Basis of Design, Record Drawing sections, and Facility Guide.
- c. Overseeing the completion of seasonal testing of HVAC&R systems during peak and swing (shoulder) seasons to verify achievement of the OPR.
- d. Facilitating the ongoing optimization of the HVAC&R systems to continue achieving the OPR.
- e. Participating in the documentation of lessons learned from this project to improve the Owner's HVAC&R systems on future projects.
- f. Facilitating the updating of HVAC&R system preventive and predictive maintenance schedules with suitable measurement and verifications documentation.
- g. Facilitating transition to an ongoing Cx for HVAC&R systems implemented by the Owner's personnel.

### **8.2 Occupancy and Operations Phase Cx Activities**

#### **8.2.1 Carry Out Occupancy and Operations Phase Cx Responsibilities**

**8.2.1.1** During the Occupancy Phase, the key CxP Team members include the CxP and the operations and maintenance personnel. Others that may be involved on the CxP Team on a periodic basis for HVAC&R systems, in addition to those listed in Guideline 0 (Section 8.2), include the mechanical contractor, HVAC&R controls contractor, systems integrator(s), and any other HVAC&R specialists (e.g., laboratory subcontractor).

**8.2.1.2** Responsibilities of the CxP Team specific to HVAC&R systems are included in SSPC 300 Informative Annex 05, "Commissioning Process Plan"

**8.2.1.3** A key focus during the Occupancy Phase is the ongoing verification of the HVAC&R related OPR, which typically include:

- a. Facility energy efficiency and conservation
- b. IAQ maintenance and documentation
- c. Occupant comfort maintenance and documentation
- d. Extraordinary-incident contingency plan maintenance and documentation

**8.2.2 Coordinate Contractor Callbacks.** During the first year of occupancy there may be occupant and user issues identified relative to the HVAC&R system and related OPR's. Therefore, it is important that the CxP Team facilitate the identification and resolution of these issues to address and document changes to the OPR and BoD and to minimize the number of contractor callbacks due to misconceptions of the occupants and users (e.g., when the outdoor air temperature is greater than design conditions, the space will become warm).

#### **8.2.3 Verify Seasonal Testing of Facility Systems and Assemblies**

**8.2.3.1** For HVAC&R systems, the OPR Cx tests need to be accomplished during the peak heating and peak

cooling conditions. For example, if the initial tests were accomplished during the heating conditions (primarily heating system tests), they would need to be re-accomplished for the cooling systems during the cooling conditions. If the initial tests were accomplished during intermediate conditions, however, then both the peak heating and peak cooling conditions tests would need to be accomplished.

**8.2.3.2** For HVAC&R systems, due to their continually changing loads and performance characteristics, it is recommended that some OPR commissioning process tests be re-accomplished during the intermediate conditions (e.g., when the facility goes from heating to cooling and when it goes from cooling to heating). It is during these intermediate conditions when the operations and maintenance staff typically have some of their most difficult issues in achieving the OPR.

**8.2.3.3** The CxP Team is responsible for working with the operations and maintenance staff and Owner's building manager on scheduling these tests. It is recommended that the operations and maintenance staff witness the tests to provide them with experience they can use to periodically verify HVAC&R system performance.

#### **8.2.4 Verify Training of Operation and Maintenance Personnel**

**8.2.4.1** An ongoing training program is developed in accordance with ASHRAE Guideline 1.3. The training program was initially planned during the Design Phase (see Section 6) and created and implemented during the Construction Phase (see Section 7). During the Occupancy Phase, any remaining training specified in the contract documents is completed and verified by the CxP Team. Examples of training typically accomplished during the Occupancy Phase include:

- a. Ongoing automated controls training.
- b. Occupant and user training on HVAC&R system limitations and operation.
- c. Ongoing training on Systems Manual upkeep.
- d. Periodic training on implementing the ongoing or continuous Cx during HVAC&R system changes.
- e. Ongoing training on new technologies and strategies to better achieve or exceed the OPR.

**8.2.4.2** Training documentation should be provided as identified in ASHRAE Guideline 1.3.

#### **8.2.5 Verify Updating of the Systems Manual**

**8.2.5.1** The Systems Manual should comply with the information provided in ASHRAE Guideline 1.4.

**8.2.5.2** The responsibility for maintaining the accuracy and relevancy of the Systems Manual is transferred from the contractors to the operations and maintenance personnel at the start of the Occupancy Phase.

**8.2.5.3** Maintaining and updating of the Systems Manual is required for the life of the facility and includes:

- a. Inclusion of material as the result of completing the Cx activities in the Occupancy Phase.
- b. Inclusion of updated maintenance procedures and schedules, ongoing operational record keeping, benchmarking results, and actions taken in the optimization of the HVAC&R system.
- c. Modifying information as changes are made to the HVAC&R systems and assemblies, including updating the OPR and BoD.

#### **8.2.6 Evaluate HVAC&R System Operations and Performance to Verify Achievement of Owner's Project Requirements**

**8.2.6.1** HVAC&R systems are dynamic and will tend to migrate from their as-installed conditions over time, and they are often affected by changes to the systems due to new occupant and user requirements. Therefore, the CxP Team must be involved throughout the first year of operation to aid the operations and maintenance staff and the Owner's building manager in achieving the OPR on a continual basis.

**8.2.6.2** At a minimum, the CxP Team needs to accomplish quarterly site visits during the first year of operation to work with the operations and maintenance staff on all the activities detailed in this phase. Ideally, the CxP Team would accomplish monthly or more frequent site visits due to their knowledge of the facility and HVAC&R systems. During these periodic operational site visits, the CxP Team should complete the following tasks:

- a. Meet with the Owner's building manager and operations and maintenance staff to identify OPR issues.

- b. Review the occupant/user complaint logs and maintenance logs for systemic issues.
- c. Review warranty items. This should be an ongoing activity for each site visit and should, at a minimum, involve a separate site visit to review warranty issues at the 10-month point of the warranties.
- d. Review completion of operations and maintenance procedures and upkeep of the Systems Manual.
- e. Review outstanding Cx issues.
- f. Discuss upcoming OPR Cx tests and additional operational site visits.
- g. Create a site visit report and document significant findings in the Issues and Resolution Log.

**8.2.6.3** As part of the first-year site visits, it is also the CxP Team’s role to facilitate the integration of the Cx activities into ongoing operations and maintenance procedures. This includes the following key activities:

- a. Maintaining the Owner’s Project Requirements document to reflect changes in use and operation of the HVAC&R systems and facility.
- b. Maintaining the Basis of Design to reflect changes in HVAC&R systems and components due to renovations or to reflect changes in the Owner’s Project Requirements.
- c. Performing periodic (seasonal, annual, or bi-annual) evaluation of achievement of the current Owner’s Project Requirements against previous benchmarks by the use of appropriate tests.
- d. Maintaining the Systems Manual to reflect changes in the Owner’s Project Requirements, Basis of Design, and systems/assemblies.
- e. Conducting ongoing training of operations and maintenance personnel and occupants on current Owner’s Project Requirements and Basis of Design, on changes in HVAC&R systems and operation, and on maintaining current Record Drawings.

#### **8.2.7 Convene Lessons-Learned Workshop**

**8.2.7.1** Using the nominal group technique detailed in ASHRAE Guideline 0, Informative Appendix I, “Owner’s Project Requirements Workshop Guidance,” convene a lessons-learned workshop.

**8.2.7.2** The attendees of this workshop are all past CxP Team members as detailed in Sections 5, 6, 7, and 8.

**8.2.7.3** The lessons-learned workshop must be facilitated by someone not directly involved with the project. This avoids conflicts of interest and enables the CxP Team members, including the CxP, to provide their input through the workshop process.

**8.2.7.4** For HVAC&R systems, the following questions may be used to generate workshop discussion:

- a. What aspects of the project (HVAC&R systems) were successful?
- b. What aspects of the project (HVAC&R systems) were not successful?
- c. What is required for your comfort in this facility?
- d. What can be done to better achieve [insert a specific] Owner’s project requirement? The intent of this question is to enable the CxP Team to focus upon a project requirement that was marginally achieved or of key importance to the project’s success; this could be comfort, energy efficiency, indoor air quality or any of a number of project requirements as defined during the Predesign Phase. This can be one or more questions.

**8.2.8 Complete Final Cx Report.** Requirements for the final Cx Report are detailed in ASHRAE Guideline 0, Section 8.2.

**8.3 Occupancy and Operations Phase Acceptance Requirements.** The Occupancy Phase acceptance requirements are detailed in ASHRAE Guideline 0, Section 8.3.

**8.4 Occupancy and Operations Phase Documentation Requirements.** The Occupancy Phase documentation requirements are detailed in ASHRAE Guideline 0, Section 8.4.

**8.5 Occupancy and Operations Phase Training Requirements.** The Cx training requirements for the Occupancy Phase are detailed in ASHRAE Guideline 0, Section 8.5.

**(This appendix is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)**

## **INFORMATIVE APPENDIX A—INTEGRATION PROJECT DESIGN**

*This appendix provides information on training requirements for HVAC&R systems and assemblies. Practitioners applying the Cx should carefully follow Guideline 0, Guideline 1.1 and other applicable commissioning technical guidelines tailored to their specific projects.*

This appendix provides examples of some of the components and subsystems that need to function properly in order for an integrated system to operate according to the Owner's Project Requirements.

Integrated building design is a process of design in which multiple disciplines and seemingly unrelated aspects of design are integrated in a manner that achieves a high degree of synergy (the working together of two or more things when the result is greater than the sum of their individual effects or capabilities). This can be achieved by integrating the design capabilities of the design team members, including those in architectural, HVAC&R, lighting, electrical, interior design and landscape design.

Major design issues should be considered by all members of the design team – from civil engineers to interior designers – who have common goals that were established during preparation of the Owner's Project Requirements (OPR) in the early planning phase of the project and then progressively updated during the project's design development. By working together in the design process, these participants can often identify effective solutions to design-integration needs that would otherwise not be found until later in the process.

After individual system functional performance has been verified, the integrated or coordinated responses between systems should be checked. The individual systems involved may be within the overall work of the building subsystem, for example, the HVAC&R system, or they may involve other systems, such as emergency systems for life safety and/or building components. This process involves concurrent testing of mechanical, electrical and building systems that are dependent on each other for successful performance in achieving the project's design intent.

During the project's Construction Phase, integrated systems testing entails monitoring the operation of multiple components and systems and verifying that their concurrent operation performs optimally.

It is sometimes desirable to simulate total building operation to ensure that all building systems are properly integrated.

The specific column that impacts a successful HVAC&R system in the integration with the exterior envelope is the mechanical column issues. The first item is of high importance, otherwise the HVAC&R systems and assemblies will be oversized or undersized if the load calculations are not integrated with the exterior envelope during the design phase, and it is a key HVAC&R checklist requirement during construction to verify the installation matches the OPR, BoD, and the construction contract documents.

**System Integration Concerns**

<b>Integrated Systems</b>	<b>Major Systems</b>	<b>Components</b>	
Mechanical	Controls	Programmable controllers	Actuators
		Terminal equipment	Point verification
	Ventilation	Sensors	Graphics
		System points	Fans
		Fans	Ductwork
		VSDs	Filters
Hydronics	Welded ducts	Air terminals	
	HEPAs	Dampers	
	Boilers	Valves	
	Chillers	Piping	
	Exchangers	Pumps	
Specialty	Coils	VSDs	
	Humidifier	Chemicals	
	Air and gas	Sprinkler	
Plumbing	Nitrogen	DX systems	
	CO <sub>2</sub>	Furnaces	
	Fuel oil		
Electrical	Normal Low/Hi Voltage	Reverse osmosis	Water heaters
		Domestic water systems	Plumbing fixtures
	Emergency	Emergency eye/shower	Sanitary/storm
		Switchgear	Breakers
		Transfer switches	Relays
		Transformers	MCCs
Lighting	Panels	UPS	
	Generator	Breakers	
	Transfer switches	Relays	
	Transformers	MCCs	
	Panels	UPS	
Communication, Security and Life Safety	Normal	Emergency	
	Panels	Panels	
	Fixtures	Fixtures	
Architectural/Structural	Structure	Relays	Relays
		Controls	Controls
		Breakers	Breakers
	Mechanical Equipment	Intercom	Security
		PA system	Bio alarm
		Fire alarm	
		Foundation	Foundation
		Curtain wall	Curtain wall
		Finish hardware	Finish hardware
		Containment	Insulation
		Coatings (epoxy)	Air barrier
		Special floorings	Windows
		Doors	Doors
		Roof	Roof
		Walls	Walls
		Hoists	Fume hoods
		Elevators & Escalators	BSCs
		Dock levelers	Autoclaves
		Prefab walk-in	Water purifier
		Freezers and coolers	Glasswash
		Lab casework	



## ANNEX R

### Exterior Enclosure System Integration

For nearly any performance criteria, system type or material pertinent to exterior enclosures, the building design team needs to consider a variety of impacts on other building systems. Some combinations can be supportive (air barriers and rain screen wall systems) yet others may be mutually exclusive (high seismic activity and a massive wall system). The following table outlines a variety of exterior enclosure topics and their associated impact on architectural, structural, mechanical and electrical issues. The “Inter-relationship” column lists other topics closely related which will also impact the design and detailing.

Exterior Enclosure Concerns							
	Material/System Type or Criteria	Inter-relations	Architectural Issues	Structural Issues	Mechanical Issues	Electrical Issues	Comments
<b>A Heat Flow Control</b>							
A.1	Increased Insulation/U-value of enclosure		Enclosure assembly may need to be thicker  Glazed areas may need to be minimized		Reduce size of ductwork and mechanical system	Reduce size of main electrical service and distribution	Most effective on structures with HVAC substantially driven by heat loss/gain loads. Not as effective on structures with high internal loads
A.2	Thermal Mass		Glazed areas may need to be maximized within selected solar orientations	Structural System may need to be concrete versus steel  Structure may need to support heavier imposed loads from enclosure	May reduce peak loads on HVAC system. May reduce size of ductwork and mechanical system	May reduce size of main electric service and distribution	
A.3	Relationship of Structure to Thermal Envelope						
<b>B Airflow Control</b>							
B.1	Air Barrier			Air barrier layer must be capable of supporting appropriate positive and negative loading	HVAC system may be reduced based on reduced air infiltration/exfiltration	Difficulty in sealing penetrations for electrical boxes may require consideration of outlet locations	

B.2	Biological/Chemical Isolation		Location of air intakes and exhausts need to be studied for security and to avoid reentrainment	Structure may need to be stiffened to reduce movement which would need to be accommodated in air tight barrier	May require differential pressurization schemes to control direction of airflow	Difficulty in sealing penetrations for electrical boxes may require consideration of outlet locations
B.3	Natural Ventilation					
<b>C Water Vapor Flow Control</b>						
C.1	Vapor Retarder	B.1, D.1				Difficulty in sealing penetrations for electrical boxes may require consideration of outlet locations
C.2						
<b>D Rain Penetration/Water Control</b>						
D.1	Drainable/Rain Screen Systems					
D.2	Thin Barrier Systems					
D.3	Massive Barrier Systems		Massive walls limit size of exterior openings. Large glazed areas may be difficult to include in design	Structural system will need to carry weight of massive walls	System may need to accommodate load from interior side drying of assembly.  Thermal swing may be sufficient to reduce peak loads and resulting HVAC system size	Savings in electrical service from reduced HVAC may be offset by need for more artificial lighting
D.4	Double Facades		Double façade may take more horizontal area at exterior envelope		HVAC system size may be reduced.  Air supply and return system may need to be designed to utilize tempered air between façade layers	Sophisticated BAS may be required to maximize effectiveness of system

D.5	High Below-Grade Watertable	Use of below grade space may need to be minimized or eliminated	Hydrostatic pressure will need to be resisted against horizontal force and uplifting force	Emergency power for pumping of foundation drains may be required		
<b>E Light, Solar, and Other Radiation Control</b>						
E.1	Daylighting	<p>Walls and/or roof require large glazed areas. Tinted, spectrally selective or other special glass may be required.</p> <p>Light shelves or other devices may be required to maximize area of building affected by daylighting.</p> <p>Glare control and shading become more important with increased glazing.</p>	<p>Large glazed openings may require special framing in enclosure assemblies.</p> <p>Sunshading devices may impose difficult cantilever loads.</p>	<p>Study required to balance effectiveness of daylighting to reduce heat gain from artificial lighting versus increased heat gain/loss resulting from glazing.</p> <p>Large areas of glazing may need to be addressed to minimize asymmetrical radiant heat loss of occupants adjacent to glass. (i.e. baseboard radiation and/or continuous slot diffusers)</p>	<p>May reduce size of main electrical service and distribution but may increase if balance of heat gain/loss is not optimized.</p> <p>BAS may get more complicated.</p>	<p>May have a substantial positive impact on user psychological comfort.</p>
E.2	Shading					
E.3	Glare Control					
E.4	Photovoltaic Generation					
E.5	Radio Frequency/ Electromagnetic Interference Control					

	Green Roof	<p>Roof membrane is on the conditioned side of roof insulation, serving also as air barrier and vapor retarder.</p> <p>Roof membrane must be more dependable, similar to water-proofing, because of difficulty to access for future repairs.</p>	Structure must support weight of soil and retained water.	HVAC system may be reduced from decreased heat gain and thermal mass.	
<b>F Noise and Vibration Control</b>					
F.1	Acoustic Insulation	<p>High frequency isolation requires multiple layers.</p> <p>Low frequency sound requires mass.</p> <p>Windows and glazing may require special details and multiple layers of special glass.</p>	<p>Structure will need to support additional mass if needed for isolation.</p> <p>Vibration isolation of structure and substructure may be required.</p>	<p>Louvers and similar penetrations through enclosure will need special detailing for isolation.</p> <p>Chillers, air handlers, and other sources of noise may need to be attenuated</p>	Generators and other sources of noise may need to be attenuated
F.2	Vibration Control				
<b>G Fire Control</b>					
G.1	Passive Fire Protection				
G.2	Active Fire Protection	<p>Systems must be coordinated to remain concealed, especially if heads are required on exterior of building.</p> <p>Wet systems on exposed side of thermal envelope need protection.</p>			Active systems require generator for emergency power.

G.3	Resistance to External Source of Fire	External materials must be selected for resistance to fire.	Structural elements need to be protected from multiple flame exposures.	Louvers and other fresh air intakes need to be located away from sources of fire and prevailing wind directions.	Emergency generators may be required if external power sources are susceptible to damage from fire. Services may need to be underground.
G.4	Catastrophic Fire Protection				
<b>H Structural Performance</b>					
H.1	Seismic Resistance				
H.2	Blast Resistance				
H.3	Break-in Resistance				
H.4	Hurricane/High Wind Loads				
H.5	Stiffness of Structure				
H.6	High-Rise Buildings				
H.7	Geotechnical Bearing Capacity				
<b>I Durability</b>					
I.1	Life Span				
I.2	High Reliability				
I.3	Microbial Growth Resistance				
<b>J Aesthetics</b>					
<b>K Value</b>					