ASHRAE Guideline 1-200X
(Supersedes ASHRAE Guideline 1-1996)

Public Review Draft

ASHRAE® Guideline

Proposed Revision of Guideline 1-1996, *HVAC&R Technical Requirements for The Commissioning Process*

First Public Review (September 2006)
(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 guideline, use the comment form and instructions provided with this draft. The draft is subject to modification until it is approved for publication by the ASHRAE Standards Committee and the Board of Directors. The current edition of any guideline or standard may be purchased from the ASHRAE Bookstore @ http://www/ashrae.org or by calling 404-636-8400 or 1-800-527-4723 (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 is a quality-oriented process for verifying and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria. The Commissioning Team uses a variety of methods and tools to verify that a project is achieving the Owner's Project Requirements throughout the delivery of the project.

Commissioning process procedures and requirements for the Commissioning Team are fully covered in ASHRAE/NIBS Guideline 0-2005 *The Commissioning Process*. That document provides adequate guidance for implementing the commissioning process for all building assemblies and systems—and for both new and existing buildings.

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

The following is a brief overview of the commissioning process as described in ASHRAE/NIBS Guideline 0-2005, *The Commissioning Process*. Guideline 0 was developed in a cooperative effort between ASHRAE and NIBS (the National Institute of Building Sciences). For simplicity, this guideline will be referred to as ASHRAE Guideline 0-2005 or Guideline 0-2005 in this document.

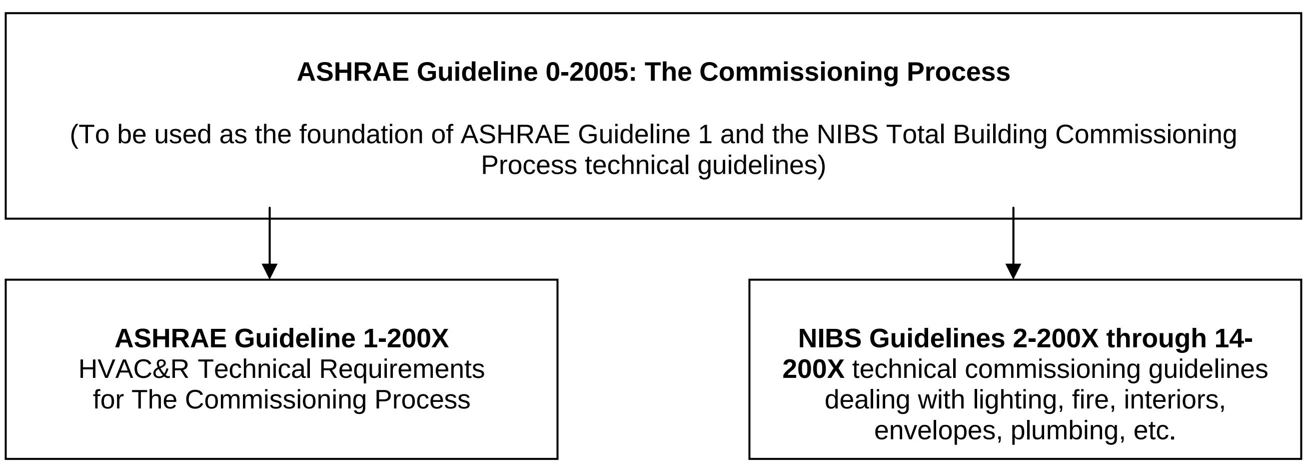
The commissioning process assumes that owners, facility programmers, designers, contractors, and building engineering, operations and maintenance (EOM) entities are fully accountable for the quality of their work. For example, the contractor is responsible for fully constructing, testing, and ensuring that his/her employees' work has provided the level of quality expected. The Commissioning Authority then randomly samples the contractor's work to verify that it is achieving the Owner's Project Requirements. If systemic issues of concern are identified, then the contractor is expected to recheck all of his/her work and correct any deficiencies. This quality-oriented commissioning process will provide improved quality and greater cost effectiveness compared to commissioning as currently practiced by many commissioning providers. One of the problems with current practice is that 100% checking is performed during the construction phase of the project delivery process and this checking usually focuses upon limited or targeted systems or assemblies. Quality-based sampling is not used and the current-practice approach has limited quality-based random inspection procedures.

Ideally, the commissioning process begins at project inception (during the Pre-Design Phase) and continues for the life of a facility (through the Occupancy and Operations Phase). The commissioning process includes specific tasks to be conducted during each phase in order to verify that design, construction, and training meet the Owner's Project Requirements. This guideline focuses upon the implementation of the commissioning process to HVAC&R systems and assemblies. It describes the specific tasks necessary to successfully implement the commissioning process for HVAC&R systems and assemblies. Because this guideline details a general process, it can be applied to both new and renovation projects and to the commissioning of existing buildings and systems.

Development of formal guidelines for HVAC&R commissioning began in 1982 when the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) established a committee to document best practices to achieve facilities that performed according to an owner's needs and requirements. ASHRAE published its original commissioning guideline in 1989, and published an updated version in 1996. In 2005 ASHRAE Guideline 0-2005, *The Commissioning Process*, was published to address the underlying quality-based commissioning process without reference to a specific discipline. Guideline 1-200X presented herein represents a revision of ASHRAE Guideline 1-1996, which contained both general commissioning process requirements and HVAC technical requirements in one document. The technical commissioning process requirements for different building systems are now being developed in individual discipline technical guidelines, separate from the commissioning process requirements that are defined in Guideline 0-2005.

Guideline 1-200X follows the format of Annex A in Guideline 0-2005 and incorporates committee experience on completed projects where systems and assemblies were expected to work from the day the project was turned over to the owner while meeting the requirements of owners, occupants, users of processes, and facility operating-maintenance-service organizations at a high level of satisfaction and where overall cost to deliver the project was reduced.

Guideline 0-2005 and Guideline 1-200X are integral parts of the National Institute of Building Sciences (NIBS) total building commissioning process guideline series. The relationship of these two guidelines to other technical commissioning process guidelines is shown below:



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 Pre-Design, 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 Pre-Design Phase. This is required for successful Occupancy and Operations Phase documentation and continuous or on-going 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 1-200X 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.

Annexes are included in this guideline to assist in the implementation of the commissioning process to HVAC&R systems and assemblies. The annexes 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 annexes 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.

A fictitious new headquarters office for ASHRAE has been used in some of the annexes to illustrate the application of the commissioning process to HVAC&R systems in buildings and facilities. These are not to be taken as illustrations of the commissioning process for an actual building, in that they were developed from several other actual projects and projected to what might be required by ASHRAE as the owner of a new building for their headquarters. They reflect what commissioning process documents and procedures that comply with this guideline might look like.

1. PURPOSE

1.1. The purpose of this guideline is to describe the technical requirements for the application of the commissioning process described in ASHRAE Guideline 0-2005 that will verify that the heating, ventilating, air-conditioning, and refrigerating (HVAC&R) systems achieve the Owner's Project Requirements.

2. SCOPE

2.1. The procedures, methods, and documentation requirements in this guideline describe the application of the commissioning process for each project delivery phase from Pre-Design through Owner Occupancy and Operation for all types and sizes of HVAC&R systems to support the commissioning process activities described in ASHRAE Guideline 0-2005, *The Commissioning Process* (also to be published by NIBS as Guideline 0-2005, *The Total Building Commissioning Process*). This includes requirements for:

(a) HVAC&R systems to fully support the commissioning process activities,
(b) verification during each phase of the commissioning process,
(c) acceptance during each phase,
(d) documentation during each phase,
(e) Systems Manual, and
(f) training for operations and maintenance personnel and occupants.

2.2. The procedures, methods, and documentation requirements apply to new construction and on-going commissioning process activities or requirements of all or portions of buildings and facilities. They also can be applied to rehab, retro-commissioning, or re-commissioning projects.

3. UTILIZATION

3.1. The application of this guideline will depend upon the Owner's Project Requirements and how the project will be designed, built, and operated. This guideline is supplemental to the commissioning process detailed in Guideline 0-2005. This guideline must be used in conjunction with Guideline 0-2005; it is not intended to be a stand-alone document.

3.2. This guideline describes specific details required to properly implement the commissioning process relative to HVAC&R systems. This includes documentation, test procedures, and checklists.

4. DEFINITIONS

Definitions for general commissioning process terms are found in Guideline 0-2005 *The Commissioning Process*. No additional HVAC&R related terms have been identified for definition herein.

5. PRE-DESIGN PHASE

5.1 Introduction

5.1.1 Pre-Design is a preparatory phase of the project delivery process in which the Owner's Project Requirements are developed and defined. Information about the project is gathered, including:

(a) Program requirements (e.g., facility interior conditions),

(b) Community context (e.g., noise from cooling towers),

(c) Codes and regulations (e.g., ASHRAE Standards 62 and 90),

(d) Site and climate (e.g., outdoor air design conditions),

(e) Facility context and function (e.g., office, hospital, refrigerated warehouse),

(f) Facility technology (e.g., heat recovery, cool storage, automation system),

(g) Sustainability (e.g., recycled material content, energy use),

(h) Cost,

(i) Schedule, and

(j) Needs and capabilities of client (owner, occupants, operators, and maintenance personnel).

5.1.2 Pre-Design Phase commissioning process objectives relative to HVAC&R systems include the following:

(a) Developing the Owner's Project Requirements,
(b) Identifying a scope and budget for the commissioning process,
(c) Developing the initial Commissioning Plan,
(d) Acceptance of Pre-Design Phase commissioning process activities.

5.2 Pre-Design Commissioning Process Activities

5.2.1 Commissioning Team Members

In addition to those team members detailed in Guideline 0-2005 (5.2.1.3), the essential members of the Commissioning Team relative to HVAC&R systems during the Pre-Design Phase should include:

(a) Facilities engineer,
(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) HVAC&R design professional,
(g) Electrical design professional.

If known or present, additional members of the commissioning team relative to HVAC&R systems during the Pre-Design Phase may include:

(a) HVAC&R equipment suppliers,
(b) HVAC&R contractors,
(c) Testing agencies, including contractors that perform TAB,
(d) Electrical contractor,
(e) Automatic controls and building automation contractors,
(f) Indoor air quality specialist,
(g) Acoustic specialist,
(h) Vibration specialist,
(i) Measurement and verification specialist,
(j) Information technology specialist,
(k) Security specialist.

Refer to Annex F in Guideline 0-2005 for details on roles and responsibilities of the above team members. See Guideline 0-2005 for the roles and responsibilities of other team members.

5.2.2 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 life cycle costing 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) Commissioning process scope and budget – a listing of HVAC&R components and systems that are the focus of the commissioning process and the budget to accomplish the commissioning process 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 – 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) User requirements – an 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.

(g) Occupant/space use requirements and schedules – an understanding of how the occupants (those with long-term occupancy of the facility) define comfort, indoor air quality, controllability, and interface with the operation and maintenance staff. Additional environmental needs may be 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 and schedules for special space use applications (e.g., refrigerated warehouse, museum).

(h) 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.

(i) Warranty requirements – a listing of the requirements for warranties on the HVAC&R systems and components, including start of warranty, period, and conditions.

(j) Benchmarking requirements – a listing of targets or benchmarks for future comparison and optimization of the HVAC&R systems. This includes energy usage, efficiencies, performance information, and capabilities of the HVAC&R systems and components.

(k) Statistical and quality 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, it should be noted that during site visits x% of the recently completed Construction Checklists are verified, or that during testing of the systems y% of the chillers and z% of the air-handling units are verified.

(l) 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.

(m) 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).

(n) Quality requirements of materials and construction – describe the level of quality, in concurrence with the life cycle cost approach, of the HVAC&R materials (e.g., the use of galvanized, stainless steel, or ceramic cooling towers), including the durability and time expectancy between failures/replacement. Document the general expectations of the Owner for the quality of construction (e.g., industry average, above average, or best workmanship).

(o) Allowable tolerance in facility system operations – document the tolerance that will be allowed in the operation of the HVAC&R systems. For example, temperature in the space shall not vary more than +/- [x] deg F, the chiller plant shall operate at +/- [x.xx] kW/ton at full load, or the system airflow shall be +/- [x] %.

(p) Energy efficiency 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 local code or owner's established criteria. Additional requirements may be stated as a percentage better than code or as a first-cost economical evaluation, such as: "any first-cost investment that will provide a simple economic payback in energy and operations cost that is less than six years should be implemented in the design."

(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), a minimum value (code or owner's internal targets), or the amount of recycled material to be used in the systems. In some projects there may be specific requirements to obtain a green rating, such as LEED™.

(r) Adaptability – document the adaptability requirements for the HVAC&R systems to be modified, expanded, or relocated for future needs.

(s) Systems integration requirements – a discussion of the need to integrate the HVAC&R systems with others, such as fire, life safety, envelope, daylighting control, and security, 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 and the specific option to be used (e.g., the indoor air quality versus the ventilation rate procedure in ASHRAE Standard 62-2004). Also include a narrative on the Owner's approach to codes, standards, guidelines, and best practices (e.g., exceed Standard 90.1 by 10%, or achieve a comfort satisfaction of 92%).

(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.
- 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.

(v) Acoustics – document the acoustic requirements for each space type (e.g., no noise production in a concert hall, background noise production in an open office space, or a maximum of RC30 in a private office). This should focus on the production of noise from the HVAC&R systems, either from the distribution of fluid or from the mechanical systems.

(w) Vibration – document an understanding of the vibration limitations of the facility and any critical use of spaces.

(x) Seismic – document an understanding of the seismic requirements, and expectations for the HVAC&R 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 – 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.
(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 of equipment that could be 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 – a narrative on the use of one or multiple backbone systems and accessibility to automatic controls and building automation systems from outside the facility.
(ee) Controls for HVAC&R systems are the key to the design, installation, and operation of these systems. The OPR needs to clearly define the level of control and interoperability of systems. Control system performance needs to be defined during the Pre-Design Phase. In some facilities this may require a brief preliminary control pre-design workshop. This is required for both the project cost budget and providing programming information for the design team and commissioning team during all phases of the project delivery.
(ff) Controls and refrigeration systems, including cool or warm storage, are sometimes limited to one or two manufacturers or vendors. To achieve the benefit of these pre-selected vendors or manufacturers, they should have representation on the commissioning team at the Pre-Design phase of the project delivery. This will continue through Design, Construction, and Occupancy and Operations Phases.

5.2.3 Scope and Budget

5.2.3.1 The focus of the commissioning process for HVAC&R systems typically involves:

(a) Energy supply (including oil supply; gas supply; coal supply; steam, hot water, and chilled water supply; solar or wind energy; and similar systems),
(b) Heat generation (including boilers, furnaces, fuel-fired heaters, auxiliaries, and similar equipment),
(c) Refrigeration (including chillers, cooling towers, refrigerant compressors and condensers, heat pumps, and similar equipment),
(d) HVAC&R distribution (including air, water, steam distribution; special exhaust; and similar systems),
(e) Terminal and package units (including unitary air-conditioning, air coils, humidifiers, dehumidifiers, terminal heat transfer units, energy recovery units, and similar equipment),

(f) HVAC&R instrumentation and controls (including electric and electronic, pneumatic, self-powered systems, and sequence of operations),
(g) Other special HVAC&R systems, equipment and controls.

5.2.4 Commissioning Plan

5.2.4.1 General requirements for the Commissioning Plan are covered in Guideline 0-2005. An illustrated supplement to the Commissioning Plan for HVAC&R is provided in Annex G.

5.2.4.2 Milestones

During the Pre-Design Phase it is critical to document key commissioning process milestones relative to the HVAC&R systems during the Design, Construction, and Occupancy and Operations Phases. These include:

(a) Pre-design meeting,
(b) Design review (multiple), including the Basis of Design requirements with each design submittal,
(c) Design Phase updated Commissioning Plan,
(d) Construction pre-bid meeting,
(e) Pre-construction meeting,
(f) Construction Phase updated Commissioning Plan,
(g) Commissioning meetings,
(h) Review of material and equipment (including control equipment) submittals, including manufacturer's operations and maintenance documentation,
(i) Coordination drawing submission,
(j) Initial Systems Manual submission (within xx days after submittal approval),
(k) Submission of automatic control and building automation controls logic diagrams,
(l) Submission of automatic control and building automation controls software xx days after submittal acceptance,
(m) Training program implementation plan,
(n) Construction Checklist completion and tracking,
(o) Equipment factory testing,
(p) Equipment placement review,
(q) Testing procedure development (update Commissioning Plan),
(r) Contractor required test verification (duct pressure testing, pipe pressure testing, etc.)
(s) Initial automatic controls and building automation system acceptance,
(t) Testing, adjusting, and balancing report and verification,
(u) Final automatic controls and building automation system acceptance,
(v) HVAC&R system testing,
(w) Final Systems Manual submission,
(x) Operator, maintenance, and occupant training,
(y) Turnover of systems/HVAC&R systems acceptance, including the start of warranties,
(z) Draft Commissioning Process Report,
(aa) Commissioning Authority site visits during first year of operation,

(bb) Operator, maintenance, occupant additional training,
(cc) Seasonal testing,
(dd) XX-month warranty walk-through and verification,
(ee) Lessons-learned meeting,
(ff) Final Commissioning Process Report.

5.2.4.3 Roles and responsibilities

The roles and responsibilities of the commissioning team members (defined in 5.2.1) relative to HVAC&R systems should be included in the Commissioning Plan. See Annex F for an example.

5.2.4.4 Pre-Design Checklists

Use the generic formats presented in Annex M of Guideline 0-2005 to develop Pre-Design Phase Checklists. Specific Pre-Design Checklists required for HVAC&R systems and components will be developed by the commissioning team during the development of the OPR. These will be used to define expectations for each submittal of documentation during the Pre-Design Phase. In established commissioning process programs, owners or project managers may have an established checklist for use by the commissioning team as they develop the OPR. Example checklists for HVAC&R components, systems, and supporting assemblies are included in Annex M of this guideline.

5.2.4.5 Design Checklists

Use the generic formats presented in Annex M of Guideline 0-2005 to develop Design Phase Checklists. Specific Design Checklists required for HVAC&R systems and components will be developed by the commissioning process team and the programming team during the development of the initial Commissioning Plan during the Pre-Design Phase. These checklists should include assemblies and systems that are essential for a successful HVAC&R installation. The checklists will define the expectations at each design submittal and will emphasize OPR, Basis of Design, and documentation expectations throughout the Design Phase. Example checklists for HVAC&R components, systems, and supporting assemblies are included in Annex M of this guideline.

5.2.4.6 Construction Checklists

The requirement for Construction Checklists should be included in the pre-design documentation to define the project needs for the design team. Use the generic formats for Construction Phase Checklists presented in Annex M of Guideline 0-2005. Determine if checklists will be in paper or electronic format for contractor completion. Specific Construction Checklists required for HVAC&R systems and components, and supporting systems and assemblies, will be determined during the Design Phase. Example checklists for HVAC&R components, systems, and supporting assemblies are included in Annex M of this guideline.

5.2.4.7 Communication Channels

The communication process between the Commissioning Team and Commissioning Authority, 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 shall be defined. This process will facilitate the review of pre-design 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 must include contact information for the Commissioning Team members and all other key project participants. For an existing building commissioning or retro-commissioning project, this may include an outside funding contact, such as the financing entity or a utility.

5.2.5 Issues Log Items

Issues Log Items shall be documented according to Section 5.2.5 of Guideline 0-2005.

5.3 Acceptance Criteria

See Guideline 0-2005, Section 5.3, for general acceptance requirements. Additional information is provided in Annex H of Guideline 0-2005 and Annex H of this guideline.

5.4 Pre-Design Phase Documentation

See Guideline 0-2005, Section 5.4, for documentation requirements. Additional information is provided in Annex D of Guideline 0-2005.

5.5 Pre-Design Phase Training Identification Requirements

See Guideline 0-2005, Section 5.5, for training identification procedures. Additional information is provided in Annex P of Guideline 0-2005 and Annex P of this guideline.

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. 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 Commissioning Plan is expanded to include details of Construction Phase and Occupancy and Operations Phase activities relative to HVAC&R systems.

6.1.2 Design Phase Commissioning Process objectives relative to HVAC&R systems shall include all requirements of Guideline 0-2005, Section 6.1.2, 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:

i. Verify that systems and components are maintainable and accessible, especially since HVAC&R systems have higher and more on-going operations and maintenance requirements than other building systems and assemblies.

ii. Optimize the life cycle cost of HVAC&R systems, in that they have the highest replacement frequency of building systems and assemblies.

iii. Verify the energy efficiency of HVAC&R systems, which are major users of energy.

iv. 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.

v. Verify that control systems requirements are clearly defined.

vi. Verify that sequence of operations and sequence of control are clear and well documented.

vii. Verify that indoor air quality and comfort requirements are analyzed and needs documented.

viii. Verify that the requirements of related HVAC&R support systems and assemblies are included in the design and that integration is adequately addressed.

ix. Verify that the design team develops adequate benchmarking of HVAC&R systems during occupancy for the Commissioning Process Team. These may be additions to Occupancy Phase benchmarks developed during Pre-Design, modifications of previous benchmarks, or recommendations to delete previous benchmarks if they do not relate to the final HVAC&R system design.

x. 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. Annex N of Guideline 0-2005 provides procedures for sampling design phase activities. Annex N of this guideline provides 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 Commissioning Process Activities

6.2.1 Design-Phase Commissioning Process Responsibilities

6.2.1.1 In addition to those detailed in Section 5.2.1 of this guideline, other members of the commissioning 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,

(e) Attorney.

6.2.1.2 Responsibilities of the commissioning team during the Design Phase are defined in Guideline 0-2005, Section 6.2.1.

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 a full table of user access levels, interoperability and connectivity, 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. Annex K of this guideline 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. Examples are given in Section 5.2.2 (t), and additional references are provided in Annex O of this guideline.

(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 Requirement is addressed in the Construction Documents.

6.2.3. Updating of Commissioning Plan

6.2.3.1. General requirements for updating the Commissioning Plan during the Design Phase are covered in Guideline 0-2005, Section 6.2.3. The Commissioning 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 Commissioning 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:

(i) Energy supply,

(ii) Safety-related systems, including alarms, fire, and power failure,

(ii) Heat generation,

(iii) Refrigeration,

(iv) HVAC&R distribution,

(v) Terminal and package units,

(vi) HVAC&R instrumentation and controls,

(vii) Other special HVAC&R systems and equipment.

(b) Schedule of HVAC&R-related commissioning process activities for the Construction Phase and for the Occupancy and Operations Phase. The schedule should identify 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) Pre-Design meeting (as a completed activity),

(b) Design review (multiple), including the Basis of Design,

(c) Updated Commissioning Plan,

(d) Construction pre-bid meeting,

(e) Pre-construction meeting,

(f) Commissioning 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 placement review,

(m) Testing procedure development (update Commissioning Plan),

(n) Initial automatic controls and building automation system acceptance,

(o) Testing, adjusting, and balancing report and verification,

(p) Final automatic controls and building automation system acceptance,

(q) HVAC&R system testing,

(r) Final Systems Manual submission,

(s) Operator training,

(t) Turnover of systems/HVAC&R systems acceptance, including the start of warranties,

(u) Draft Commissioning Process Report,

(v) Commissioning Authority site visits during first year of operation,

(w) Seasonal testing,

(x) Lessons-learned meeting,

(y) Final Commissioning Process Report.

6.2.4 Commissioning Process Requirements in the Construction Documents

6.2.4.1. Integrate specific component performance 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 commissioning process activities into the relevant HVAC&R specification divisions as required. See Guideline 0-2005, Section 6.2.4, for general requirements. A guide specification section template for HVAC&R commissioning process requirements is provided in Annex L of this guideline.

6.2.5 Construction Checklists

6.2.5.1. Annex M of this guideline contains sample formats for typical HVAC&R Construction Checklists. See Section 7.2 of this guideline for further information.

General requirements for Construction Checklists are presented in Guideline 0-2005, Section 6.2.5.

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 0-2005, Section 6.2.6, and Annex O of this guideline 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, and similar equipment),

(c) Refrigeration (including chillers, cooling towers, refrigerant compressors and condensers, heat pumps, and similar equipment),

(d) HVAC&R distribution (including air, water, steam distribution; special exhaust; and similar systems),

(e) Terminal and package units (including unitary air-conditioning, air coils, humidifiers, dehumidifiers, terminal heat transfer units, energy recovery units, and similar equipment),

(f) HVAC&R instrumentation and controls (including electric and electronic, pneumatic, self-powered systems, and the sequence of operations),

(g) 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 are outlined in Guideline 0-2005, Section 6.2.7. Annex P of this guideline provides 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 and Operations 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 commissioning authority 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, daylighting). Training should involve operator training, maintenance training, repair training, and on-going training for HVAC&R systems. In addition to the factory training elements, VFDs, boilers, pumps, air-handlers, and terminal boxes always have on-site training requirements. Additional guidance on training is provided in Guideline 0-2005, Section 6.2.7.

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 Guideline 0-2005, Section 6.2.8, including recommended sampling rates for the commissioning process verification activities described in Section 6.2.8.4. Specific to HVAC&R systems, the following guidance is provided for the four-step review process in Guideline 0-2005, Section 6.2.8.2. The intent of the design review by the commissioning team is to determine if there are systematic errors, not to fully check the drawings and specifications. The responsibility for the complete checking of the drawings and specifications for coordination and accuracy remains with the design team.

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 (such as chillers, condensers, boilers, pumping systems, and sequence of controls) and random samples (10-20%) of other portions (e.g., air-handlers, terminal devices, exhaust fans, control devices) 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 easy maintenance 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 commissioning team will only review a sample of the specifications, typically only 10-20% for HVAC&R systems, to verify the design team has a quality process and are meeting the OPR. Items checked include applicability of the section to the project, Commissioning Process 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 Guideline 0-2005, Section 6.3, for Design Phase acceptance requirements.

6.4 Design Phase Documentation Requirements

Refer to Guideline 0-2005, Section 6.4, for Design Phase documentation requirements.

6.5 Design Phase Training Identification Requirements

Refer to Guideline 0-2005, Section 6.5 for Design Phase training requirements.

7. CONSTRUCTION PHASE

7.1 Introduction

Commissioning process activities to be performed by the various members of the commissioning team during the Construction Phase are described in Guideline 0-2005, Section 7. Additional information on specific activities relative to HVAC&R systems is presented in this section and includes:

(a) Updating of Construction Checklists prepared during the design phase to reflect the specific equipment/materials approved by the design professionals.

See Annex M of this guideline for representative examples of HVAC&R Construction Checklists.

(b) Providing or updating of test protocols not addressed earlier in the commissioning process because specific product information had not yet been received. See Annex U of this guideline for representative examples of HVAC&R test protocols.

(c) Verifying that the control logic diagrams and any additional controls programming that has been created can achieve the Owner's Project Requirements. Refer to Sections 7.2.7.3 and 7.2.9.4 for further guidance.

(d) 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. Refer to Section 7.2.9.5 for further guidance.

(e) Verifying the testing, adjusting and balancing (TAB) work for HVAC&R air and water systems. Refer to Section 7.2.7.5 for further guidance.

(f) Verifying scheduling of seasonal and occupancy-dependant testing. Refer to Section 7.2.13.3 for further guidance.

7.2 Construction Phase Commissioning Process Activities

7.2.1 Carry Out Construction Phase Commissioning Process Responsibilities

7.2.1.1 Essential HVAC&R commissioning team members, in addition to those listed in Guideline 0-2005 (Section 7.2.1.4), 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.

7.2.1.2 Responsibilities of the Commissioning Team include the following activities that are specific to HVAC&R. See Annex F of this guideline 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. This includes controls, TAB, duct and pipe layout, equipment room layout, maintenance-troubleshooting parts lists requirements, ceiling space coordination, and underfloor coordination.

(b) In addition to HVAC&R submittals, the HVAC&R-focused commissioning team needs to review related submittals to verify that lighting and power loads in spaces and building envelope thermal assemblies meet the Basis of Design for cooling, heating, ventilating, and refrigerating loads.

(c) Other related systems with submittals that should be reviewed to verify that they meet the Basis of Design include smoke evacuation systems, 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 Guideline 0-2005, Sections 5.2.2.8 and 7.2.2, 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 commissioning activities that will occur during construction. It is very important that bidders understand their roles in the commissioning process. This is also an opportune time to discuss the reason for including the Owners 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 on-going commissioning after construction is completed. Bidder questions regarding the commissioning requirements should be addressed with appropriate responses to all bidding contractors.

7.2.3 Coordinate Owner's Representatives Participation

Refer to Guideline 0-2005, Section 7.2.3, for a general description. The HVAC&R construction commissioning process may include, but is not limited to, the following participants:

(i) Facility engineer,

(ii) Refrigeration personnel,

(iii) Heating shop personnel,

(iv) Building controls personnel,

(v) Electrical shop personnel,

(vi) Pipefitters,

(vii) Boiler and chiller plant operators.

7.2.4 Update Owner's Project Requirements

Refer to Guideline 0-2005, Section 7.2.4, for general guidance. If proposed HVAC&R changes that are at variance with the Owner's Project Requirements are approved by the design professionals and owner, 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 Commissioning Plan

7.2.5.1 Refer to Guideline 0-2005, Section 7.2.5.

7.2.5.2 Specialists with knowledge of specific systems and equipment may be utilized as resources for the HVAC&R commissioning team and listed in the commissioning plan, with roles and responsibilities. The HVAC&R system commissioning process activities may include specialists in the following areas:

(i) High pressure boiler,

(ii) Acoustics,

(iii) Fume hood,

(iv) Laboratory controls,

(v) Water treatment,

(vi) Power quality,

(vii) Radio frequency interference,

(viii) Systems integration,

(ix) Computerized maintenance management systems.

7.2.6 Conduct Pre-Construction Commissioning Process Meeting

7.2.6.1 Refer to Guideline 0-2005, Section 7.2.6.

7.2.6.2 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

7.2.7 Verify Submittals

7.2.7.1 Refer to Guideline 0-2005, Section 7.2.7 and Annex M, for general procedures and sampling strategies.

7.2.7.2 Coordination drawings 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 and component vendor submittals shall be obtained for use by the commissioning authority. This information, when confirmed and approved, shall be used in developing the Construction Checklists and test procedures.

7.2.7.4 Submittal of the HVAC&R sequence of control should be presented in the form of a control logic diagram or other approved format.

7.2.7.4 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 Annex O).

7.2.7.5 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 site 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) Detailed step-by-step procedures for TAB work, including terminal flow calibration (for each terminal type), diffuser proportioning, branch/submain proportioning, total flow calculations, rechecking,

(i) Description of what system diversity is utilized and how it will be simulated,

(j) Specific and verifiable procedures used to obtain the lowest practical pressures for both the air and water side and a record of operating pressures in each system,

(k) Details of procedures and conditions to be used for specified air and water capacity tests,

(l) Narrative to demonstrate that TAB specialist clearly understands outdoor air ventilation criteria under all conditions,

(m) Details of procedures to verify and set minimum outdoor air quantity. Procedures should define at what levels minimum outdoor air quantity will be verified (total building, zone, etc.), when required by the specifications,

(n) Details of procedures for how building static pressures and exhaust fan/relief damper capacity will be checked as specified for various operating modes.

(o) Identification of measuring instruments to be used by type, manufacturer, model, serial number, and their most recent calibration date.

(p) Proposed selection of points for sound measurements.

(q) Details of any TAB work to be done in phases (by floor, for example), or of areas to be built out later,

(r) Details regarding specified deferred or seasonal TAB work,

(s) Procedures to measure and adjust required building and room pressure differentials,

(t) 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),

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

7.2.8 Schedule Construction Phase Commissioning Process Activities

7.2.8.1 In addition to the general requirements in Guideline 0-2005, Section 7.2.8., the following commissioning process activities for HVAC&R systems should be scheduled and coordinated with the construction schedule:

(a) Submittals, including, but not limited to, equipment approval, coordination drawings, control interface wiring diagrams,

(h) Order of HVAC&R testing,

(i) Pipe and duct leak testing. Verification of leak testing of piping and ductwork, flushing and cleaning of piping systems, and cleaning of ductwork, air and hydronic systems TAB, HVAC components and system testing,

(d) HVAC equipment installation and startups,

(e) Site utilities testing,

(f) BAS control system testing,

(g) Testing, adjusting and balancing,

(h) Commissioning tests,

(i) Test verification.

7.2.9 Develop Test Procedures

7.2.9.1 In addition to the general test procedure requirements in Guideline 0-2005, Section 7.2.9, 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.

(j) Each project requires creation of test procedures unique to that project. Therefore, the following discussion is intended to convey the thought process used to create a test procedure. The list of test procedures and the sample test procedures and data forms in Annex U may be used as a starting point.

(k) 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.

(l) The first step in developing a test procedure is to determine which OPR items require a test procedure for verification. In order to accomplish this, the commissioning 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.

(m) The second step in developing a 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:

(i) East cooling/west heating,

(ii) Peak load design conditions (minimum diversity),

(iii) East heating/west cooling,

(iv) Peak wet-bulb condition.

(n) The third step in developing a test procedure is to identify what information must be documented to show OPR achievement (refer to Section 7.2.10 of this guideline).

(i) 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,

(ii) 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,

(iii) 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 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 commissioning authority, prior to scheduling the test.

(b) The following should be accomplished prior to the start of any commissioning process OPR tests:

(i) Verify control system operation after TAB verification.

(ii) Verify functionality and compliance with intent for each individual sequence module in the sequences of operation,

(iii) 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,

(iv) Verify all alarm and high- and low-limit functions and messages generated on all points with alarm settings,

(v) Verify integrated performance of all components and control system components, including all interlocks and interactions with other equipment and systems,

(vi) Verify shutdown and restart capabilities both for scheduled and unscheduled events (e.g., high pressure shutdown and normal scheduled start/stop),

(vii) Verify proper sequencing of heat transfer elements as required to prevent inappropriate simultaneous heating and cooling,

(viii) Verify sequencing of multiple stages or sources of heat transfer, refrigeration, and heat generation element capacities,

(ix) Verify control system stability and tuning by upsetting various control loops under different load conditions and observing the system response,

(x) When applicable, demonstrate a full cycle from off to on and no load to full load and then to no load and off,

(xi) Verify time-of-day schedules and set points,

(xii) Verify all energy-saving control strategies,

(xiii) 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,

(xiv) 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 commissioning process, 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 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 Guideline 0-2005, 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 Commissioning Team Meetings

7.2.11.1 Commissioning 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 Guideline 0-2005. The meetings may or may not be conducted within a regularly scheduled commissioning meeting. Attendees should include all parties and disciplines affected by the subjects under consideration. Such meetings might include:

(a) HVAC&R installation, startup and testing,

a. Equipment coordination within the HVAC&R discipline,

b. Review of construction checklist procedures,

(b) Review of Owner's Project Requirements verification test procedures,

(c) Control system implementation and coordination,

(d) Pre-TAB preparation,

(e) Review of TAB report,

(f) Review of Issues Log.

7.2.11.2 Special Coordination Meetings

(a) Verification Protocol and Construction Checklist meetings. Essential HVAC&R Commissioning Team members, in addition to those listed in Guideline 0-2005, 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) Commissioning Team Meetings. Convene special commissioning team meeting(s) as required to address the control system and the TAB activities.

(i) 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 commissioning authority, 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.

1. A meeting early during construction may be held with the mechanical designer, commissioning authority, 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.

2. Control package submittal content requirements and scheduling, including products, sequence of control, control logic diagram, and control software.

3. On-going point-to-point control system verification requirements as well as other information on the Construction Checklists.

4. Resolution procedures to be followed.

5. Documentation submittal requirements and timing.

6. Involvement in commissioning test completion at end of the project.

(ii) 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 commissioning authority, 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.

1. Sequencing of events (equipment Construction Checklist completion, control system Construction Checklist completion, system start-up, TAB, TAB verification, commissioning testing completion).

2. TAB contractor test report forms and submission procedures.

3. Review of commissioning process checklists, submission procedures, and frequency.

4. Identification, documentation, and resolution of issues identified by TAB contractor.

5. 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 take into account 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 Annex N 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 0-2005, the following contractors:

(a) Sheet metal contractor,

(b) Mechanical piping contractor,

(c) Controls 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 Annex M provides examples of HVAC&R Construction Checklists.

7.2.13.5 Annex U provides an example of a “comfort” OPR commissioning process test procedure and data forms. A sample Issues Log/Resolution Log is included.

7.2.14 Verify Training

See Guideline 0-2005 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 Commissioning Process Report

See Guideline 0-2005, Section 7.2.15, for requirements.

7.2.16 Verify Systems Manuals Update

See Guideline 0-2005, Section 7.2.16, for requirements.

7.2.17 Verify updates to Basis of Design

See Guideline 0-2005, Section 7.2.17, for requirements.

7.3 Construction Phase Acceptance Requirements

See Guideline 0-2005, Section 7.3, for requirements.

7.4 Construction Phase Documentation Requirements

See Guideline 0-2005, Section 7.4, for requirements.

7.5 Construction Phase Training Requirements

See Guideline 0-2005, Section 7.5, for requirements.

8. OCCUPANCY AND OPERATIONS PHASE

8.1 Introduction

Commissioning process activities described in this section to be performed by the various members of the commissioning team during the Occupancy and Operations Phase are generally described in Guideline 0-2005, 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 proper contractor and/or design professional when required.

(b) Verifying on-going upkeep of project documentation in the Systems Manual, especially the Owner's Project Requirements, Basis of Design, and Record Drawing sections.

(c) Overseeing the completion of seasonal testing of HVAC&R systems during peak and swing seasons to verify achievement of the OPR.

(d) Facilitating the on-going 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 or continuous commissioning process for HVAC&R systems implemented by the owner's personnel.

8.2 Occupancy and Operations Phase Commissioning Process Activities

8.2.1. Carry Out Occupancy and Operations Phase Commissioning Process Responsibilities

8.2.1.1. During the Occupancy and Operations Phase, the key commissioning team members include the Commissioning Authority and the operations and maintenance personnel. Others that may be involved on the Commissioning Team on a periodic basis for HVAC&R systems, in addition to those listed in Guideline 0-2005 (Section 8.2.1.2), 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 commissioning team specific to HVAC&R systems are included in Annex F of this guideline.

8.2.1.3. A key focus during the Occupancy and Operations Phase is the on-going 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

8.2.2.1 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 commissioning 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).

8.2.2.2 The following steps should be followed in the documentation and resolution of HVAC&R system issues:

(a) Occupant/user documents each issue on a standard form.

(b) The form is sent to owner's building manager, and a copy is then sent to the commissioning team, for review.

(c) The commissioning team reviews for impact on OPR and provides input to owner's building manager on how to resolve issue (e.g., if a contractor is required to visit the site, which contractor(s) should be called).

(d) The commissioning team updates the OPR/BOD when changes to the HVAC&R systems occur during issue resolution.

(e) The commissioning team periodically reviews all issues to identify process improvement opportunities and systemic issues that need to be addressed.

(f) A formal response is sent to the original occupant/user concerning the resolution of the issue or why it could not be resolved.

(g) The commissioning team documents the issue through the issues log and assigns appropriate costs when relevant.

8.2.3. Verify Seasonal Testing of Facility Systems and Assemblies

8.2.3.1. For HVAC&R systems, the OPR commissioning process tests need to be accomplished during the peak heating and peak cooling season. For example, if the initial tests were accomplished during the heating season (primarily heating system tests), they would need to be re-accomplished for the cooling systems during the cooling season. If the initial tests were accomplished during an intermediate season, however, then both the peak heating and peak cooling seasons 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 seasons (e.g., when the facility goes from heating to cooling and when it goes from cooling to heating). It is during these intermediate seasons when the operations and maintenance staff typically have some of their most difficult issues in achieving the OPR.

8.2.3.3. The commissioning 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 accomplish the tests under the supervision of the commissioning team to provide them with hands-on testing experience they can use periodically to re-verify HVAC&R system performance. The various contractors should be invited to the testing, but their involvement does not need to be part of their scope of work.

8.2.3.4. Follow the guidance on OPR testing provided in Section 7 of this guideline and in Guideline 0-2005.

8.2.4. Verify Continual Training of Operation and Maintenance Personnel

8.2.4.1 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 and Operations Phase, any remaining training specified in the contract documents is completed and verified by the commissioning team. Examples of training typically accomplished during the Occupancy and Operations Phase include:

(a) On-going automated controls training.

(b) Occupant and user training on HVAC&R system limitations and operation.

(c) On-going training on Systems Manual upkeep.

(d) Periodic training on implementing the on-going or continuous commissioning process during HVAC&R system changes.

(e) On-going training on new technologies and strategies to better achieve or exceed the OPR.

8.2.5. Verify Continual Updating of the Systems Manual

8.2.5.1. 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 and Operations Phase.

8.2.5.2. 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 commissioning process activities in the Occupancy and Operations Phase.

(b) Inclusion of updated maintenance procedures and schedules, on-going 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, including updating the OPR and BOD.

(d) Keeping the record documents current with changes in walls, nomenclature, systems, and assemblies.

8.2.6. Periodically Evaluate HVAC&R System 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 commissioning 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 commissioning 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 commissioning team would accomplish monthly or more frequent site visits due to their knowledge of the facility and HVAC&R systems.

8.2.6.3 During these periodic operational site visits, the commissioning team should complete the following tasks:

(a) Meet with the owner’s building manager and operations and maintenance staff to identify OPR issues. This is accomplished by reviewing the OPR with them and having them identify areas of concern.

(b) Review the occupant/user complaint logs and maintenance logs for systemic issues.

(c) Review warranty items. This should be an on-going 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 commissioning process issues.

(f) Discuss upcoming OPR commissioning tests and additional operational site visits.

(g) Create a site visit report and document significant findings in the Issues Log.

8.2.6.4 As part of the first year site visits, it is also the commissioning team's role to facilitate the integration of the commissioning process activities into on-going 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 on-going 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 Guideline 0-2005 Annex I, convene a lessons-learned workshop.

8.2.7.2. The attendees of this workshop are all past commissioning team members as detailed in Section 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 commissioning team members, including the commissioning authority, 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 commissioning 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 Pre-Design Phase. This can be one or more questions.

8.2.8. Complete Final Commissioning Process Report

Requirements for the final Commissioning Process Report are detailed in Guideline 0-2005, Section 8.2.5.

8.3 Occupancy and Operations Phase Acceptance Requirements

The Occupancy and Operations Phase acceptance requirements are detailed in Guideline 0-2005, Section 8.3.

8.4 Occupancy and Operations Phase Documentation Requirements

The Occupancy and Operations Phase documentation requirements are detailed in Guideline 0-2005, Section 8.4.

8.5 Occupancy and Operations Phase Training Requirements

The commissioning process training requirements for the Occupancy and Operations Phase are detailed in Guideline 0-2005, Section 8.5.

ASHRAE Guideline 1-200X– HVAC&R Technical Requirements for The Commissioning Process

Index to Annexes

Annex A – Guide for Developing Supplementary Technical Guidelines for the Commissioning Process.

Annex A is part of ASHRAE Guideline 0-2005. It is a normative annex to Guideline 0-2005, but is <u>not applicable</u> to any Supplementary Technical Guidelines. The purpose of Annex A is to provide the recommended format and content for the Total Building Commissioning Process supporting technical guidelines. The Annex A in Guideline 0-2005 describes a uniform sequence of Annexes for all Supporting and Technical Commissioning Process Guidelines.

In general, when a specific Annex topic does not require additional information to support Guideline 0-2005, it will be left blank and it will be noted either that the annex is <u>non-applicable</u>, that the Guideline 0-2005 Annex <u>is also applicable to this guideline</u>, or that <u>additional information is not required</u>. A uniform labeling of all Annexes in all Guidelines is required when complying with Guideline 0-2005, Annex A. This is the reason for labeling some annexes as not applying. For example, this will assure that Annex G always contains information on the Commissioning Plan.

Annex B – Commissioning Process Flowchart

Refer to ASHRAE Guideline 0-2005. *Annex B is an informative annex to Guideline 0-2005, and <u>additional information is not required</u> for this guideline.* The purpose of Annex B (ASHRAE Guideline 0-2005) is to provide an illustration of the general flow of the commissioning process.

Annex C – Cost and Benefits of the Commissioning Process

Refer to ASHRAE Guideline 0-2005. *Annex C is an informative annex to Guideline 0-2005, and <u>is also applicable to this guideline</u>.* The purpose of Annex C is to provide a context for the application of the commissioning process.

Annex D – Commissioning Process Documentation Matrix

Refer to ASHRAE Guideline 0-2005. *Annex D is an informative annex to Guideline 0-2005, and <u>is also applicable to this guideline</u>.* The purpose of Annex D is to provide a summation of documentation requirements for the commissioning process.

Annex E – Commissioning Process Request for Qualifications

Refer to ASHRAE Guideline 0-2005. *Annex E is an informative annex to Guideline 0-2005, and <u>is also applicable to this guideline</u>.* The purpose of Annex E is to provide a sample request for qualifications for commissioning process services.

Annex F – Roles and Responsibilities

Refer to ASHRAE Guideline 0-2005. *Annex F is an informative annex to Guideline 0-2005, and is also applicable to this guideline.* The purpose of Annex F is to provide an overview of the various participants to the commissioning process. The text of this guideline expands upon the information in Annex F with respect to HVAC&R commissioning activities.

Annex G – Commissioning Plan

Annex H – Acceptance Plan

Refer to ASHRAE Guideline 0-2005. This is a normative annex to Guideline 0-2005, but is not applicable to this guideline. The purpose of Annex H is to provide the recommended format and content for Total Building Commissioning Process supporting technical guidelines.

Annex I – Owner's Project Requirements Workshop Guidance

Annex J – Owner's Project Requirements

Annex K – Basis of Design

Annex L – Specifications

Annex M – Construction Checklists

Annex N – Quality-Based Sampling Examples

Annex O – Systems Manual

Annex P – Training Manual and Training Needs

Annex Q – Publications, Articles, References, Codes, Regulations, and Standards

Annex R – Integration Requirements

Annex S – Interference and Coordination with Other Systems and Assemblies

Annex T – Communications: What, When, and Who

Annex U – Test Procedures and Data Forms

Annex V – Pre-Design Phase Commissioning Process Specific Needs

This pre-assigned Annex in Guideline 0-2005 is not used for HVAC&R.

Annex W – Design Phase Commissioning Process Specific Needs

This pre-assigned Annex in Guideline 0-2005 is not used for HVAC&R.

Annex X – Construction Phase Commissioning Process Specific Needs

This pre-assigned Annex in Guideline 0-2005 is not used for HVAC&R.

Annex Y – Occupancy & Operations Phase Commissioning Process Specific Needs

This pre-assigned Annex in Guideline 0-2005 is not used for HVAC&R.

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

INFORMATIVE ANNEX G

COMMISSIONING PLAN

This annex provides an example of how to implement part of Guideline 1-200X. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X, and other applicable commissioning technical guidelines tailored to their specific projects. An example of another technical guideline is NIBS Guideline 3-2006, Exterior Envelope Technical Requirements for the Commissioning Process.

This example Commissioning Plan is for a fictitious New ASHRAE Headquarters and is based upon information from other commissioning process projects. It is not related to any actual project.

The Commissioning Plan is an essential document to plan and carry out the commissioning process. It provides all process participants with an understanding of commissioning principals and how to apply them. The following example is presented to illustrate one possible facility.

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Commissioning Plan Overview

The purpose of the Commissioning Plan is to provide a clear and concise roadmap for the implementation of the commissioning process and to provide a record of the results of the commissioning process. Since the Commissioning Plan contains the results of the process, it can be considered a living document where the results are added throughout the process. Therefore, to simplify the upkeep of the document, the basic process and procedures to be followed throughout the project are detailed in the main body of the Commissioning Plan. The materials and information that are developed during the commissioning process are included in the appendices.

This Commissioning Plan has been specifically developed for the ASHRAE Headquarters Facility project. The process and procedures in this Commissioning Plan have been specifically tailored to this project.

As mentioned above, the structure of this Commissioning Plan is the main body and the appendices. The specific sections include:

- Commissioning Process Description: This section provides an overview of the tasks being accomplished during the commissioning process. The information is tailored for the ASHRAE Headquarters Facility, focusing specifically on each phase of the project – pre-design, design, construction, and occupancy and operations.

- Pre-Design Phase: Provides a detailed description of the commissioning process activities to be accomplished during the pre-design phase of the project.

- Design Phase: Provides a detailed description of the commissioning process activities to be accomplished during the design phase of the project.

- Construction Phase: Provides a detailed description of the commissioning process activities to be accomplished during the construction phase of the project.

- Occupancy and Operations Phase: Provides a detailed description of the commissioning process activities to be accomplished during the occupancy and operations phase of the project.

- Contact Information: Provides detailed contact information for members of the Commissioning Team for quick reference.

- Schedule Requirements: There are specific sequences of events that must occur during the commissioning process. These events are detailed in this section.

- Appendices: Presents the information developed during the commissioning process. As work is completed, the results are added to the proper appendix and the status and date of the document are inserted into the table below.

Appendix	Name	Status	Comments
A	Owner's Project Requirements	Version 3	Current at 100% CD
B	Basis of Design	Version 2	Bid Set Version
C	Project Specifications	Completed	Bid Set Version
D	Communication Structures	Completed	
E	Roles and Responsibilities	Completed	
F	Commissioned Systems	Completed	
G	Commissioning Process Schedule	Draft	Integrated with Project Schedule
H	Pre-Bid Meeting	To be completed	
I	Pre-Construction Meeting	To be completed	
J	Design Submittal Review Criteria	Completed	
K	Submittal Review	To be completed	
L	Commissioning Process Issues	To be completed	Part of Contractor's Software Program
M	Construction Checklists	To be completed	Separate Book
N	Systems Manual	To be completed	Completed by Contractor
O	Tests	To be completed	
P	Training	To be completed	
Q	Meeting Minutes	To be completed	Part of Contractor's Software Program
R	Correspondence	On-Going	
S	Warranty Review	To be completed	
T	Lessons Learned	To be completed	

Commissioning Process Description

The intent of this section is to provide an overview of the tasks being accomplished as part of the commissioning effort for this project. The subsequent sections provide guidance on how these activities are to be accomplished for each phase of the project.

The general approach taken in implementing the commissioning process on this project is a prescriptive and sequential in order to focus the commissioning efforts on verifying that the OPR has been achieved. Details on the results of actually accomplishing the tasks are contained in the appendices.

Pre-Design Phase

The tasks to be accomplished during the pre-design phase are:

- Develop Owner's Project Requirements
- Develop Initial Commissioning Plan
- Track Commissioning Process Issues

Develop Owner's Project Requirements

The Owner's Project Requirements (OPR) is a written document that details the functional requirements of a project and the expectations of how it will be used and operated. This includes project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information. The OPR document is a condensed collection of vital information about a construction project. The document is intended for a wide audience, including the owner, design team, construction team, operation and maintenance staff, future renovation teams, and anyone else who needs access to the original project information. The OPR is not a substitute for traditional architectural programming. It does contain some programming information, such as space usage. The OPR can be considered a living document because it is updated during design, during construction and during occupancy. This document is provided to the building owner upon completion of the project so that the information it contains is not lost over time.

Because the Commissioning Process began at the end of project design, the Commissioning Authority (CxA) shall interpret the existing project documents and establish the OPR with the project team, and finalize the initial draft. With this initial draft, the CxA shall maintain the OPR throughout all phases of the project and verify that the OPR is being achieved.

See Appendix A for the current OPR.

Develop Initial Commissioning Plan

Development of this initial commissioning plan involves deciding on the format of the plan, inserting the initial information, documenting the communication structures for the project, documenting of the roles and responsibilities relative to the commissioning process, identifying the systems to be commissioned, and developing initial commissioning schedule requirements.

The construction version of the commissioning plan will be created after contractor selection and will be provided to the owner, to the A/E, and to the contractors in three ring binders. The commissioning authority will send updates to the commissioning plan electronically. Holders of a copy of the commissioning plan should then add paper copies of the updates to their three ring binders – typically just appendix additions.

Track Commissioning Process Issues

Throughout the commissioning process, the commissioning authority will identify and track the resolution of commissioning process issues, which are defined as a finding that does not meet the OPR.

The documentation of each commissioning issue goes beyond the traditional description of the issue, who is responsible, and due date. The primary reason for this is that if the commissioning process works as it is supposed to, the owner, A/E, and contractor do not have problems at the end of construction.

To avoid the inevitable question--Why did we pay for commissioning?--the issues database also includes the cost to resolve each issue identified and the savings achieved as a result of resolving the issue. This cost information is meant to show the value that commissioning contributed to the project, i.e., costs the owner would have incurred if commissioning was not done, and should not be used for other purposes.

The cost saving associated with each Commissioning Process Issue is determined in a three-step process:

1. Identify and Record Issues – the documentation of the issue will be accomplished in the general contractor's project software program and will be tracked utilizing the "Issue Type" field in the software – selecting "Commissioning."

2. Calculate Avoided Costs – Commissioning Authority will determine which issues are to be included in the cost analysis. Possible reasons for excluding a particular issue from a cost analysis could be lack of adequate cost information, negligible effects on the project outcome, or commissioning playing a minimal role in the issue. Costs will be determined based upon the Commissioning Authority's professional judgment and may include, but are not limited to, actual implementation costs (if a change order is required), industry reference materials such standardized unit costs, and calculations of energy use or additional maintenance labor.

3. Evaluate Range of Avoided Costs – typically there could be a wide range of avoided costs. Suppose, for example, that during mock-up construction of a VAV box, it was determined that it could not be maintained. There are two possible scenarios to the avoided cost. The first scenario (maximum avoided cost) is if the issue was never identified during construction and the owner has long-term costs in both energy and maintenance. The second scenario (minimum avoided cost) is if the issue was identified early in construction and was resolved through a redesign change order, with cost to the A/E to redesign and to the contractor to relocate the VAV boxes. By estimating the range of avoided cost, the entire project team is provided with feedback on the value of commissioning.

The commissioning authority will provide periodic updates via email to the owner, A/E, and the contractors on issues that are in the process of being resolved. Issues that have been resolved will be added to the issues log in the commissioning plan during the periodic updates of the commissioning plan.

Appendix L will contain the commissioning process issues log.

Design Phase

The tasks to be accomplished during the design phase are:

- Review and Modify Project Specifications
- Verify Basis of Design
- Update Commissioning Plan
- Accomplish Design Reviews
- Develop Commissioning Process Contract Document Requirements
- Conduct Pre-bid Meeting

Review and Modify Project Specifications

There will be specific commissioning process requirements included in the contractor's specifications, such as specific equipment and component performance documentation and construction checklists with appropriate cross-references. The requirements will be included into Division 01 through 49 Sections, and the obligations to perform these requirements must be in the contract between the Owner and Contractor. A detailed scope and responsibilities of the Contractor will be included in the "Summary of Work" section of Division 01. The commissioning process requirements for documentation, training, and testing facility systems and assemblies are integrated into the commissioning sections of Divisions 01 through 49. Furthermore, responsibility for development of specification input documents will be given to the commissioning authority because the responsibility of implementing and entering information will be that of the owner, A/E, and contractors.

These specification documents will also include the format in which contractor submittals and other submittals will be presented, training requirements deemed necessary, construction checklist development and completion, commissioning process test development, System Manual requirements, and so on. With procedures for communication finalized, these documents will be arranged in the list of deliverables that have an origin of development and a final destination of the person(s) who review such documents.

See Appendix C for the commissioning process input to the project specifications.

Verify Basis of Design

The Basis of Design is created and maintained by the design team to document how their design achieves the OPR. The design team provides their current Basis of Design document with each design submittal. The commissioning authority is responsible for reviewing the Basis of Design against the OPR to verify achievement of the OPR, to identify any inconsistency with the design team, and to resolve the inconsistency by changing the design (provided that the design team agrees to change) or changing the OPR (provided that the owner agrees to the change).

Update Commissioning Plan

The commissioning plan is a living document, requiring updating as the project progresses. During the design phase, additional details are added to how the commissioning process will be implemented during construction and the specific roles and responsibilities of key team members refined. The structure of the commissioning plan is such that most of these changes will be through the addition of material to the appendices.

Accomplish Design Reviews

This step is critical in the Commissioning Process since it is the responsibility of the commissioning authority to review the design submittals to verify achievement of the OPR. These design submittals are provided by the design team. The commissioning authority follows a specific procedure for design review in order to evaluate achievement of the OPR and the identification of systemic issues.

A design review will be accomplished at each of the following design submittals:

- Programming Document
- Schematic Design
- Design Development
- 35% Construction Documents
- 95% Construction Documents
- 100% Construction Documents

The specific information to be reviewed for in each design submittal is detailed in Appendix J

When possible, three distinct reviews are complete on a drawing set – a general review, a coordination review, and field-specific review. A review of the specifications and supporting documentation is also accomplished.

General Review

The general review entails a look at the general quality characteristics of 10% of the design documents. Characteristics to look for include the legitimacy of the drawing set, legibility of information, continuity and labeling, and component details. Also, the OPR information should be included on the drawings. The criteria for this general review include:

- Legibility – all text and notes are legible and understandable
- Continuity – walls, pipes, and other systems that leave one page are shown entering the other page
- Consistency – notes and details are properly referenced and are pertinent
- Backgrounds – the same architectural backgrounds are used by all disciplines
- Room Numbers – room numbers are clearly defined and consistently applied from room to room and between disciplines

Coordination Review

The coordination review is accomplished to verify that the design team has coordinated their efforts between the various disciplines. This review utilizes random sampling of the drawings. Random sampling encompasses taking a random section of the drawing and reviewing this section for all trades (landscaping, architectural, structural, plumbing, mechanical, electrical, etc.). This is done for each architectural drawing sheet. The following is accomplished to complete the coordination review:

- Select sampling grid – utilize a 5x3 grid density and mark the cover page of the drawing set with the grid. Drill a hole through the drawing set at each grid intersection.
- Determine sampling frequency – utilize 15% for this project. This means every 7th grid is chosen – start with grid 7 for the 7% review. If there is no equipment or systems to review in the selected grid, proceed to the next grid until coordination can be confirmed. It is desirable to review coordination in both relatively open areas (e.g., office space) and relatively tight areas (e.g. hallways).
- For each selected grid:
    - Locate identical grid area on other discipline sheets.
    - Review for key OPR (maintainability, accessibility, constructability, and durability)
    - Document both discrepancies and achievement of the OPR
- Review discrepancy list for systemic issues.
- Develop listing of systemic issues and one-time issues for A/E to address.

Field Specific Review

The field specific review is to determine if a specific discipline achieved the OPR in the selection of their components and design of their systems. A random sampling procedure is again utilized for this verification. The same grid layout is used as was used for the coordination review. The sampling frequency is 15%. Grids that are completely blank (no walls, equipment, etc.) are not included in the counting.

The specific OPR criteria are used for evaluating the success of each discipline's drawings. For each selected grid, accomplish the following for any component or system within the grid:

- Compare to each OPR criterion – mark as pass or fail
    - Sizing calculations
    - Basis of design
    - Schedules
    - Details
    - Specifications
    - Maintainability, accessibility, and constructability
- Interface with other systems
- Opportunity for improvement

Throughout this field specific review, problems found or concerns for items are documented with detailed notes. Both systemic and one-time issues are identified and documented.

Specification and Other Documentation Review

In this review, a review of the general quality of the specification for the design documents and other documentation is performed. The review also involves random rational sampling in that 5% of the documents are reviewed. Although the actual details are checked in Field Specific Review, specification and other documentation review will focus on such specifics as excessive information, manufacturer listings, clear and concise design directions, and a clearly stated Basis of Design.

Design Review Comments

The comments documented during the design review are collated and a report generated. These comments are provided to the design team. They will be discussed at a design review meeting following receipt of design review comments – the intent is to resolve the issues, not create more.

Develop Commissioning Process Contract Document Requirements

Throughout the commissioning process, certain activities that pertain to quality-assurance and quality-control procedures must be performed as part of the construction contract. Included in the contract documents will be the OPR and Basis of Design, which will only be used for informational purposes in order to differentiate it from the contractor's contractual obligations. This aids the contractors in understanding the design and material requirements, any sustainability goals, and the desired use and intent of the facility. This information will aid the successful implementation of the commissioning process.

In addition, the draft construction checklists are completed during the construction-documents development phase of design. The commissioning authority is responsible for creating the draft construction checklists and obtaining concurrence on the level of detail, format, and implementation with the owner.

The construction checklists will be maintained in Appendix M

Attend Pre-Bid Meeting

The commissioning process activities have been integrated into the contractor's specifications. The commissioning authority will attend this pre-bid meeting to explain the key differences in this project to educate the contractors on the benefits of commissioning and the procedures for implementation.

The results of this meeting that are applicable to the commissioning plan will be summarized in Appendix H. It will include the contractor's input and updates to the construction documents that are applicable.

Construction Phase

During construction phase, the tasks to be accomplished include:

- Conduct Pre-Construction Meeting
- Perform Contractor Submittal Review
- Verify Construction Checklists
- Review Training
- Complete Testing

Conduct Pre-construction Meeting

Once the contractor is selected, the commissioning authority will attend and participate in the pre-construction meeting. The role of CxA during the meeting will be to review and discuss the OPR and the communication protocols the project team has developed. As part of this meeting, the commissioning authority will discuss each segment of work to be commissioned to emphasize how the commissioning plan will be implemented. The commissioning authority will emphasize the importance of achieving the OPR.

The results of this meeting that are applicable to the commissioning plan will be summarized in Appendix I. It will include the contractor's input and updates to the construction documents that are applicable.

Perform Contractor Submittal Review

A major interface between the commissioning authority and the contractors will be the reviewing of the contractor submittals for completeness and ability to meet the OPR. The commissioning authority will provide the contractor a listing of submittals that will be reviewed upon receipt from the contractor of their submittal log.

Reports detailing the commissioning authority comments and suggestions regarding the submittal review will be provided to the design professionals and owner and will be included in Appendix K.

Verify Construction Checklists

The construction checklists are developed by the commissioning authority during the design phase and modified during construction mobilization, maintained by the general contractor, and used by the general contractor and subcontractors. They will be tracked utilizing a procedure acceptable to the owner. The intent of construction checklists is to convey pertinent information to the installers regarding the owner's concerns on long-term operation of the facility and systems.

The approach to the structure of the checklists is to keep it short and simple by focusing on key elements. When information is known (manufacturer, model, etc), this information is included on the checklist when it is provided by the commissioning authority. When multiple components are to be installed (lights, etc.) and information specific to each component is not required, then there shall be generic checklists that are not specific to a particular piece of equipment. The construction checklists are typically composed of three primary sections:

1. Delivery Book – information to be verified upon delivery to the site.
2. Pre-Installation Checks – items to verify prior to installation (may have been in storage for weeks or months).
3. Installation and Start-up Checks – items to verify during each installation step and at start-up.

The checklists span the duration from the time when the equipment is delivered to the job site until the time that the system/component is started up and is operational. This includes testing, adjusting, and balancing (TAB) and control system tuning.

The development of the construction checklists takes close coordination between the commissioning authority and contractors to maximize the benefits of the checklists and to tailor the checklists to the way the contractors will manage the project.

During each site visit the commissioning authority will randomly verify 2-5% of the construction checklists completed since the commissioning authority's previous site visit. Both positive and negative items from this review are to be conveyed to the project team.

Appendix M contains sample Construction Checklists.

Review Training

The commissioning authority will review the contractor's submitted training agenda and materials to verify that the OPR is properly represented and beneficial to the end user. Commissioning Authority will attend key training sessions to verify that they are conducted properly and that the contractor understands the expectations of training. The following tasks are accomplished during the construction phase:

- Review contractor's training agenda and materials.
- Attend key training sessions.
- Verify purpose of training is understood.
- Document results along with recommendations and the issues resolved.

Results from the Training Program are located in Appendix P.

Complete Testing

The purpose of the commissioning process tests is to verify that the building systems as a whole meet the performance requirements stated in the OPR. Before this testing can be conducted, the individual components and systems must be verified for proper operation. This verification is accomplished as part of the construction checklist activity and typically includes the verification of individual control loops, point-to-point testing, and TAB (testing, adjusting, and balancing).

Random sampling will be used to conduct the commissioning process tests. The tasks for developing and utilizing the tests include:

- Review OPR and identify testing criteria.
- Review submittals for equipment restrictions and testing procedures.
- Develop testing schedule.
- Develop draft test procedures.
- Obtain contractor and owner input.
- Finalize test procedures.
- Oversee accomplishment of testing by the contractors.
- Complete test data records.
- Verify results of tests.
- Retest if necessary.
- Document results, conclusions, and any recommendations.

The results of these tasks are located in Appendix O.

Occupancy and Operations Phase

The tasks to be completed in the occupancy and operations phase include:

- Final Commissioning Process Report
- Seasonal Testing
- Ongoing Training
- Warranty Review
- Lessons-Learned Meeting

- Initial Commissioning Report
- Systems Manual
- Warranty Reviews
- Lessons Learned
- Final Commissioning Report

Final Commissioning Process Report

The final commissioning process report will essentially be the filling in of the commissioning plan. This will minimize the potential for excess paperwork and rework. An executive summary and a summary of the project will be added along with all the documented issues. Included in the executive summary will be the commissioning authority's evaluation of achievement of the OPR and recommendations on resolving any issues related to not achieving the OPR. The whole report will be scrutinized for completeness and accuracy.

Seasonal Testing

The commissioning authority will coordinate the completion of any seasonal commissioning process testing required. The facility operations and maintenance personnel will actually perform the seasonal tests under the direction of the commissioning authority. This provides the operations and maintenance personnel with hands-on experience that will help maintain the OPR for the life of the facility.

Ongoing Training

The commissioning authority will verify the completion of any ongoing training provided by the contractor, including the updating of the systems manual and other project documentation.

Warranty Review

At the 10-month point of occupancy, the commissioning authority will conduct a site visit with the owner to critically review the operation of the system and components to identify any items that should be repaired or replaced under warranty. A warranty review will include the following tasks.

- Review system warranties.
- Schedule a site visit.
- Meet with owner's operation and maintenance personnel.
- Document the issues.
- Provide recommendations to owner and contractor.
- Include results in final commissioning process report.

Results for the warranty review will be located in Appendix S.

Lessons-Learned Meeting

Because the commissioning process is based on the principal of quality, the lessons learned should always be analyzed for the purpose of providing continuous improvements to the process. The commissioning authority will convene a lessons learned meeting that will document the issues that arose in the commissioning process. This meeting will usually be conducted at end of the first year of operation and involve the owner's entire party, design professionals, contractors, and the commissioning authority.

To minimize bias by the commissioning authority, this lessons learned meeting will be facilitated by a third party (typically someone from the owner or the commissioning authority's firm not involved in the project).

Results from the Lessons Learned meeting will be located in Appendix T.

Contact Information

Role	Person	Company	Address	Phone	Cell	Fax	E-mail
Commissioning Authority (CxA)							
CxA - Mechanical Engineer							
CxA - Control Systems Engineer							
CxA - Electrical Engineer							
CxA - Life Safety Systems							
CxA - Laboratory Equipment							
Owner							
O&M Representative							
Owner's Representative							
Architect							
Structural Engineer							
Mechanical Engineer							
Electrical Engineer							
General Contractor							
Mechanical Contractor							
Sheet Metal Contractor							
Controls Contractor							
TAB Contractor							
Fire Protection Contractor							
Electrical Contractor							
Vertical Transport Contractor							
Ceiling Contractor							
HVAC Piping Contractor							

Schedule Requirements

The following table describes the key milestones to be accomplished as related to the commissioning process activities. The first column labels the key milestone to be accomplished, and the second and third columns declare who is responsible for accomplishing that milestone.

Milestone	Project Milestone	Commissioning Milestone
OPR		
Develop Specification Input		
Commissioning Plan		
Programming Document Review		
Schematic Design Review		
Design Development Review		
Controls Coordination Meeting		
35% Construction Document Review		
95% Construction Document Review		
100% Construction Document Review		
Project Schedule		
Pre-bid Meeting		
Pre-construction Meeting		
Construction Checklist		
Contractor Submittals		
Submittals Review		
System Manual Submittals		
Site Visits		
Develop Commissioning Process Tests		
Accomplish Commissioning Process Tests		
Complete Commissioning Process Test Report		
Site Visits		
Systems Manual Review		
Training Agenda Review		
Training Sessions		
Training Results		
Operation & Warranty Review 1		
Operation & Warranty Review 2		
Final Commissioning Process Report		
Lessons Learned Meeting		

[Table will be filled in as project schedule is developed.]

SUPPLEMENTAL INFORMATION- INDEX

Appendix A – Owner's Project Requirements

Appendix B – Basis of Design

Appendix C – Project Specifications

Appendix D – Communication Structures

Appendix E – Roles and Responsibilities

Appendix F – Commissioned Systems

Appendix G – Commissioning Process Schedule

Appendix H – Bid Meeting

Appendix I – Pre-Construction Meeting

Appendix J – Design Submittal Review Criteria

Appendix K – Submittal Review

Appendix L – Commissioning Process Issues

Appendix M – Construction Checklists

Appendix N – Systems Manual

Appendix O – Tests

Appendix P– Training

Appendix Q– Meeting Minutes

Appendix R – Correspondence

Appendix S – Warranty Review

Appendix T – Lessons Learned

The following is a description of information and documentation for each Appendix in the Commissioning Plan.

Appendix A – Owner's Project Requirements

(*Insert OPR as described in Guideline 1-2006 Annex J)*

Appendix B – Basis of Design

(Insert BOD as described in Guideline 1-2006 Annex K)

Appendix C – Project Specifications

(Insert project specifications at the completion of design phase with any revisions at the completion of the project)

Appendix D – Communication Structures

(Develop project specific reporting, communication, and approval protocols to supplement contractor procedures)

Appendix E – Roles and Responsibilities

(Summarize project specific responsibilities extracted from the Annex F's in Guideline 0-2005, and Guideline 1-2006 such as provided below)

Team Members

The members of the commissioning team consist of the CxA, assigned members of the CM/GC, DESIGN PROFESSIONAL (particularly the mechanical engineer), the mechanical contractor, electrical contractor, TAB representative, controls contractor, any other installing subcontractors or suppliers of equipment. The Owner's building or plant operator/ engineer is also a member of the commissioning team.

General Management Plan

The CxA is hired by the Owner. In general, the CxA coordinates the commissioning activities and reports to the Owner. The CxA's responsibilities, along with all other contractors' commissioning responsibilities are detailed in the specifications. The Specifications will take precedence over this Cx Plan. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents. Refer to the management protocols section below.

General Descriptions of Roles

General descriptions of the commissioning roles are as follows:

CxA:	Coordinates the Cx process, writes tests, oversees and documents performance tests
GC:	Facilitates the Cx process, ensures that Subs perform their responsibilities and integrates Cx into the construction process and schedule
Subs:	Demonstrate proper system performance
DP	The Design Professionals perform construction observation, approve O&M manuals and assist in resolving problems
PM:	Facilitates and supports the Cx process and gives final approval to the Cx work
Mfr.:	The equipment manufacturers and vendors provide documentation to facilitate the commissioning work and perform contracted startup

Appendix F – Commissioned Systems

(Develop a project specific listing of the systems to be commissioned, such as the following:

<u>HVAC System (and all integral equipment controls)</u>

- _X_ Chiller system (including controls, chillers, cooling towers, piping, pumps and variable speed drives)
- _X__ Pumps
- _X__Variable speed drives
- ____ Process Coolers
- _X__ Piping, cleaning and flushing
- _X__ Chemical treatment
- _X_ Ductwork
- _X__ Air handling and Fan Coil units
- ____ Roof top packaged DX units (heat pumps or AC)
- ____ Split systems
- _X__ Terminal units
- _X__ Testing, Adjusting and Balancing work
- _X__ Unit and Cabinet heaters
- _X__ Building automation system (controlled devices, control loops and system integration)

<u>Electrical Systems</u>

- _X__Lighting controls
- ___ Electrical system power quality
- ___ Communications system
- ___ Security system
- _X__ Emergency power systems
- _X__ Uninterruptible power supply system

<u>Life Safety Systems</u>

- _X__Fire alarm system
- ___ Egress pressurization systems
- _X_ Fire suppression/protection systems

<u>Other</u>

- ____ Elevator
- ____ Kitchen exhaust equipment
- ____ Refrigeration equipment and systems

Appendix G – Commissioning Process Schedule

(Develop a project specific schedule of commissioning functions to supplement contractor's construction schedules)

Appendix H – Bid Meeting

(Insert bid meeting agenda(s) and minutes as they become available)

Appendix I – Pre-Construction Meeting

(Insert pre-construction meeting agenda(s) and minutes as they become available)

Appendix J – Design Submittal Review Criteria

(Develop project specific criteria from OPR requirements to use in submittal review and reporting)

Appendix K – Submittal Review

(Insert results of reviews when available)

Appendix L – Commissioning Process Issues

(Develop and utilize a reporting procedure for the tracking of pre-design, design, construction, and occupancy/operations phases issues, such as the following:)

COMMISSIONING ISSUES/BENEFITS LOG

#: ___________ (assigned by database)

Project Name: ____

Project ID: ____

Attach additional pages as necessary for issues requiring more explanation and tracking.

Prepared by: ____ Date: __________________

Distribution: ____

Date found: ____________________ Submitter of Issue: ______________________________

Issue: ____

____

____

____

Effects: ____

____

____

____

Possible Cause: ____

____

____

Recommendations: ____

____

____

Response Date: ____

Actions Taken: ____

____

____

Responsible Person: __________________________ Fix Date: __________________________

Impact on or Issues related to the Systems Manual:

____

____

____
____

Benefits
Economical Range $__________ to $____________________
Most Probable Certain Benefit to Owner: $________________
Most Probable Benefit to Design Team: $ _________________
Most Probable Benefit to the Construction Team: $__________
Non-Economic Benefits to the Building:
____
____
____

Page _____ of ___________

Appendix M – Construction Checklists

(Develop and utilize construction checklists as shown in Guideline 1-2006 Annex M)

Appendix N – Systems Manual

(Assemble systems manuals as described in Guideline 1-2006, annex O)

Appendix O – Tests

(Develop test procedures and acceptance criteria based on the OPR and specific system and equipment requirements)

Appendix P– Training

(Develop training plans and schedules as described in Guideline 1-2006 Annex P)

Appendix Q– Meeting Minutes

(Insert meeting minutes as they become available)

Appendix R – Correspondence

(Insert copies of relevant correspondence as it becomes available)

Appendix S – Warranty Review

(Insert copies of warranty review(s) when available)

Appendix T – Lessons Learned

(Insert copy of lessons learned reports when available)

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

INFORMATIVE ANNEX H
Acceptance Plan

This annex provides an example of how to implement part of Guideline 0-2005. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005 and the applicable commissioning technical guidelines tailored to their specific projects.

Developing and documenting the acceptance procedures in an acceptance plan is an important task for the successful implementation of the Commissioning Process. The acceptance plan details the key Commissioning Process activities that must be accomplished at the end of each phase in a project in order to move on to the next phase.
The following provides a description of the details that should be included in the acceptance plan and illustrates a format that could be used.

Pre-Design Phase

The Owner's Project Requirements and the Commissioning Plan are formally accepted by the Owner during the Pre-Design Phase after review and comment by the Commissioning Authority. The general process for accepting these documents is:

1. Commissioning Authority develops a draft of each document and provides to the Commissioning Team.

2. The Commissioning Team provides comments on the draft documents.

3. The Commissioning Authority works with the Commissioning Team to resolve any issues.

4. The Commissioning Authority recommends to the Owner acceptance of the documents and provides copies for review.

5. Owner reviews the modified documents and accepts.

Design Phase

Updated Owner's Project Requirements, updated Commissioning Plan, Basis of Design, and Contract Documents are formally accepted by the Owner during the Design Phase. The Owner's Project Requirements and the Commissioning Plan follow the same process as detailed in the Pre-Design Phase.
The general process for accepting the Basis of Design is:

1. Commissioning Authority provides a list of information required and the format for the Basis of Design to the design professionals prior to the start of design.

2. The design professionals gather and organize the information during the creation of the design.

3. The design professionals submit the Basis of Design to the Owner and Commissioning Authority for review and comment with each design submittal.

4. Upon correction and re-submittal, the Owner accepts the Basis of Design based upon the recommendation of the Commissioning Authority.

The general process for accepting the Contract Documents is as follows:

1. The design professionals submit the final package to the Owner and Commissioning Authority for review.

2. The Commissioning Authority evaluates the Contract Documents using random sampling and evaluates the documents for achieving the Owner's Project Requirements.

3. The Commissioning Authority meets with the design professionals to discuss and resolve comments.

4. Upon resolution of comments, the Commissioning Authority recommends to the Owner acceptance of the documents.

5. Owner reviews the comments and their resolution, and accepts the Contract Documents.

Construction Phase

Updated Owner's Project Requirements, updated Commissioning Plan, updated Basis of Design, Systems Manual, training program, and a preliminary and a final Construction Phase Commissioning Process Report are formally accepted by the Owner during the Construction Phase. The Owner's Project Requirements, Commissioning Plan, and Basis of Design follow the same process as previously detailed.
The general process for accepting the Systems Manual is:

1. The Commissioning Authority tracks the Contractor submittals for the required documentation.

2. Within **<insert number of days>** days of submittal acceptance for a system or assembly, the Contractor submits a draft Systems Manual to the Owner, Commissioning Authority, and design professionals.

3. The Commissioning Authority consolidates the reviews and meets with the design professionals to discuss and resolve.

4. The Contractor submits to the Commissioning Authority changes to the accepted submittals throughout construction.

5. **<insert number of days>** days prior to the first training session, the Contractor submits the final Systems Manual to the Owner, Commissioning Authority, and design professionals.
6. The Owner accepts the final Systems Manual based upon the recommendation of the Commissioning Authority.

The general process for accepting the training program is:

1. The Commissioning Authority provides the training agendas to the Contractor.

2. The Contractor develops the training program, including identifying the trainer, the schedule of sessions, and the material to be developed. This information is submitted to the Owner, Commissioning Authority, and design professionals for review and comment.

3. Based upon the recommendation of the Commissioning Authority, the Owner accepts the training program.

4. The Contractor develops the training material and submits to the Owner, Commissioning Authority, and design professionals for review and comment <**insert number of days**> days prior to the first training session.

5. Based upon the recommendation of the Commissioning Authority, the Owner accepts the training materials.

6. The Contractor implements the training program.

7. The Commissioning Authority randomly quizzes the trainees 2 weeks after the completion of a session.

8. The Contractor submits copies of all training materials and edited videotapes of the sessions.

9. The Commissioning Authority recommends acceptance of training program completion to the Owner.

The general process for accepting the facility is as follows: << revised (terminology)

1. Throughout construction the Commissioning Authority randomly samples the completion of the Construction Checklists for achieving the Owner's Project Requirements.

2. The Commissioning Authority directs the completion of system and assembly testing by the Contractor and documents the results.

3. The Commissioning Authority works with the Contractor in resolving any issues identified during testing.

4. The Commissioning Authority verifies that all system documentation is received from the Contractor.

5. The Commissioning Authority presents a preliminary Construction Phase Commissioning Process Report prior to occupancy that provides an evaluation of achieving each OPR, including recommendations to the Owner for acceptance/rejection of the facility.

6. The Commissioning Authority provides a final Construction Phase Commissioning Process Report with details on the Commissioning Process Activities completed during the Construction Phase. << added

Occupancy and Operations Phase

Updated Owner's Project Requirements, updated Basis of Design, updated Systems Manual, seasonal test results, and Commissioning Process Report are formally accepted by the Owner during the Occupancy and Operations Phase. The Owner's Project Requirements, Basis of Design, and Systems Manual follow the same process as previously detailed for other phases.
The general process for accepting the seasonal test results is:

1. The Commissioning Authority directs the completion of seasonal system and assembly testing by the Contractor and documents the results.

2. The Commissioning Authority works with the Contractor in resolving any issues identified during testing.

3. The Commissioning Authority verifies that all updated system documentation is received from the Contractor.

4. The Commissioning Authority recommends to the Owner acceptance of the seasonal testing results.

The general process for accepting the Commissioning Process Report is:

1. The Commissioning Authority provides the Commissioning Process Report to the Owner, design professionals, and Contractor for review and comment.

2. The Commissioning Authority incorporates comments and provides a final copy to the Commissioning Team members.
3. The Owner accepts the Commissioning Process Report, ending the Commissioning Authority's responsibilities.

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

INFORMATIVE ANNEX I

Owner’s Project Requirements Workshop Guidance

The Owner’s Project Requirements are the heart of the commissioning process. Developing the OPR can be done in a comprehensive workshop that includes the owner, facility users, maintenance personnel, design team, commissioning authority and other appropriate participants. Guideline 0-2005 describes the process in detail in annex I.

The following questions are examples that may be asked during the workshop, as defined in Guideline 0-2005 Annex I, relative to HVAC&R systems. The italicized text provides comments on the questions to help explain them.

1. What areas are required for a functional facility? *This question gets the attendees to define the areas of the facility that are required for functionality (e.g., classrooms, restrooms, administration, etc. for an elementary school). The interaction of these functions is also functions guides the layout and equipment locations.*

2. List conditions important to your comfort in an ideal building. *This question gets the attendees to define what comfort is on their terms and provides the design engineer with information they traditionally do not get. This information often goes beyond the temperature, humidity and air circulation parameters.*

3. What activities generate pollutants in this building? *This question provides an understanding of the activities that are perceived to produce pollutants. The benefit is that the architect and engineer can determine how to avoid health and comfort problems through design or process changes.*

4. How do we make this facility more sustainable? *This question provides a clear understanding of how the owner defines sustainability. The responses from this question can then be applied to typical green rating systems (e.g., LEED™ and BREAM™).*

5. How do you define energy efficiency? *This question is for the O&M staff and is intended to understand how they determine the energy efficiency of the building and what level of efficiency is acceptable. This might also include equipment preferences and measurement and verification requirements.*

6. How will you benchmark system operation? *This question is for the O&M staff and provides information on how they will measure the performance of the building. This is key to selecting the building control and energy management systems.*

7. What documentation is required to properly operate and maintain facilities? *This question is for the O&M staff and provides input on what documentation they require and how they will use it. The format and information depth of the systems manual is defined at this time.*

8. What are your training requirements? *This question is for the O&M staff, and sometimes the occupants, to determine what is needed to understand the systems and building. The knowledge base of the expected maintenance crew is key to defining the training requirements specified in the construction and commissioning documents.*

9. What problems with previous projects should be avoided? *This question is intended to understand what problems have occurred on previous projects so that we can avoid them on this project.*

10. What must be accomplished for a successful project? *This question is typically not asked and often results in misunderstandings. By understanding how the team is going to evaluate the success of the project, the designers will be able to meet the expectations. Validation and testing requirements are often defined at this time.*

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

INFORMATIVE ANNEX J

OWNER'S PROJECT REQUIREMENTS

This annex provides an example of how to implement a part of Guideline 1-200X. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X, and applicable commissioning technical guidelines tailored to their specific projects. This example is a fictitious New ASHRAE Headquarters, based upon information from other commissioning process projects. It is not related to any actual projects.

The Owner's Project Requirements document is a written summary of the facility requirements including design, usage, efficiency, documentation, testing and training to provide the required functions. The following example is presented to illustrate one possible facility.

New ASHRAE Headquarters Facility

(Note: Pages numbers are illustrative, not pages in this Guideline)

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Introduction

The new ASHRAE Headquarters Complex is being initiated to meet the needs of ASHRAE through the year 2040 and is intended to provide a single point of resource for membership, community, staff, and honored guests.

As the international leader in the heating, ventilating, air conditioning, and refrigerating (HVACR) sciences, ASHRAE believes it is essential that this facility not only include, but highlight those technologies that are fundamentally sound, sustainable, and flexible to meet the current and future needs.

ASHRAE has adopted the total building commissioning process as detailed in ASHRAE/NIBS Guideline 0 as their quality-oriented process for achieving, verifying, and documenting that the performance of the facility, systems, and assemblies meets their defined objectives and criteria as defined in this document.

The focus of the commissioning process is on key systems and assemblies, including:

- [insert other building systems and assemblies as detailed in other companion technical guidelines]

- HVAC systems
  - Hot water system
  - Chilled water system
  - Air distribution systems
  - Building automation system

Due to lack of internal resources, the owner is utilizing a third party Commissioning Authority with a direct contract to the owner. The scope of work to be accomplished by the Commissioning Authority and their firm includes the following key activities:

- Development and maintenance of the Commissioning Plan
- Facilitating an OPR Workshop and development of OPR document
- 6 design reviews (programming document, schematic, design development, first construction documents, second construction documents, and final construction documents)
- Integration of commissioning process into design documents, including construction checklists, testing of system to verify OPR achievement, documentation, and impact of non-compliance
- Contractor's Pre-bid meeting
- Pre-construction meeting
- Submittal OPR verification review
- [W] construction site visits and meetings to verify on-going achievement of OPR by contractor (once a month for first [X]% of construction, twice a month for [Y]% of construction, and once a week for [Z]% of construction)
- Controls coordination meeting
- Testing of HVACR systems to document Owner's Project Requirement achievement
- 12 occupancy and operations site visits

- Seasonal testing of HVACR systems to document Owner's Project Requirement achievement
- 10-month warranty review
- Lessons-learned meeting

Key Owner's Project Requirements

From input gained during the OPR workshop and subsequent follow-up, several key OPR have been identified that are absolutely critical to the success of this project. These OPR are general in nature and essentially encompass the performance criteria and detailed OPR contained throughout this document.

For HVACR systems in this project, the key OPR are:

- Project documentation requirements – in order to properly install, start-up, operate, troubleshoot, and maintain the HVACR systems for the life of the facility, accurate and accessible documentation is required. The owner requires all documentation to be electronic and tailored to the specific components installed. For HVACR systems, the timing of completion of key documentation is essential:

    - Draft Systems Manual within [X] days of submittal approval.
    - Training Material [X] days prior to system start-up.
    - Final Systems Manual [X] days prior to final acceptance.

- Owner directives – the following are the directives from the owner to the design team. Each directive has been related to underlying Owner's Project Requirements.

    - Use [X] control manufacturer – all existing facilities utilize manufacturer [X] and maintenance technicians are conversant on their system – this is related to the maintainability OPR, whereby using a common, known control system will simplify the operation of the facility.

    - Use only a screw chiller – good part load performance is desired due to highly variable loads and partial occupancy expected in the future – this is related to the energy efficient operation OPR and flexibility of the system.

    - Do not use interior duct lining – owner wants to minimize the potential for indoor air quality problems – this is related to the indoor air quality OPR.

    - Do not use fan powered terminal units – concern over fan inefficiencies and system energy use – this is related to the energy efficiency OPR.

- Appropriate heating and cooling - The HVACR system must provide consistent and individually controllable temperature, humidity, and airflow during at occupied periods.

Comment: Note that the Project Documentation and Owner Directive OPR are always required for HVACR systems, per the guidance provided in AHSRAE/NIBS Guideline 0 Annex N.
Note that some of the OPR are non-HVACR related, but are included as these OPR are impacted by the HVACR systems.

- Efficient and adequate work space - The spaces must be designed to provide ample work and support areas to facilitate the operations of the building rather than hamper them.

- Image enhancement – ASHRAE Headquarters is the primary point of physical interaction with the public. The image that AHSRAE projects must reflect the importance of the building and the overall image of the Society. The building shall be a showcase for the Society and for Atlanta.

- Flexibility - The building must be able to respond to the changing needs of the occupants. This includes flexibility in space layouts, heating and cooling systems, lighting, and utilities (phone, electric, data, etc.)

- Sustainability - The design and construction of the building must take into account all long term and life cycle issues. The building systems must be easily maintainable by contracted maintenance personnel, with easy and non-disruptive access to components and systems for routine maintenance. All building systems shall be designed and installed for the lowest possible life cycle cost, which takes into account both the first cost of the item/material and its long term operating costs. As a part of making this facility a showcase and benchmark for the Society members, the materials, systems, and construction methods chosen for this project shall have the least possible environmental impact. Obtain USGBC LEED™ certification at a level of silver or higher.

General Project Description

The new ASHRAE Headquarter project has been undertaken to meet the expanded needs of the organization and to provide the foundation for the next 40 years of growth, sustainability, and maintaining the international leadership within the HVACR sciences. This project is not only a replacement of the existing headquarter facility, but is intended to highlight sustainability and HVACR technologies, maximize employee productivity, and provide flexibility to meet the Society's needs throughout the life of the facility.

ASHRAE desires to achieve a high quality design with minimal requests for information or change orders to avoid project delays. Therefore, sufficient time is allotted to the pre-design phase and the design phase for review and verification of achievement of the Owner’s Project Requirements. The key project milestones are:

Milestone	**Estimated Date of Completion**
OPR completed	
Program Completed	
Schematic design	
Design development	
1st construction document review	
2nd construction document review	
Final construction documents	
Pre-bid meeting	
Award contract	
Pre-construction meeting	
All submittals approved	
Structural frame complete	
Facility sealed	

Milestone	Estimated Date of Completion
Major HVACR equipment installed	
Startup	
Testing	
Tuning	
Substantial completion	
Warranty start date	
Lessons learned workshop	

There are several restrictions and limitations that are fixed for this project due to its location and goals of the owner. These restrictions and limitations are detailed below and become part of the Basis of Design created by the design professionals.

- [insert non-HVACR restrictions and limitations]

- Noise restrictions – due to the proximity of the property to adjacent facilities, particularly hotels, noise generated by the HVACR systems must not project past the property line.

- Water pressure limitation – the water pressure at the main take-off is 20 psig due limitations in the city's distribution system.

- Building height restriction – the building height is limited to 50 feet due to local codes.

Comment: Note that the building height restriction does affect the HVACR systems due to the relationship of ductwork size to supply air temperature and due to the options for placement of HVACR components.

It is the owner's intent to meet or exceed the local codes and standards in place at the time of permitting or known revisions in the process of being adopted. In addition, the requirements of any relevant ASHRAE Guideline or Standard that has been published shall be met or exceeded by this project.

Objectives

There are several key objectives that the owner wishes to achieve during this project. These include:

a. System accessibility and maintainability - The design and construction of the building must be energy efficient to operate and maintain. The new building systems must be easily maintainable by staff maintenance personnel, with sufficient access to systems for routine maintenance.

b. Heating and cooling - The heating, ventilating, and air conditioning system will provide the appropriate thermal comfort for its occupants while providing environmentally sound and energy efficient operation. The system must provide consistent and individually controllable temperature and airflow.

c. Allowable tolerance in facility system operations – the tolerance that will be allowed in the operation of the HVACR systems is:

    - Temperature in the space shall not vary more than +/- 2°F from head to foot and from space to space.

- System airflow shall not vary more than +[X]% from design values (which dictates that it must not go below design values).

d. Energy efficiency goals – the HVACR system energy efficiency goal is to be 15% higher than ASHRAE Standard 90.1 [current version] requirements and achieve an EnergyStar™ rating of at least 80.

e. Environmental and sustainability goals – the owner defines sustainability for HVACR systems as:

- No use of CFC's or HCFC's
- Use of 10% recycled content in all metal products
- Highly durable systems (long lifetime)
- System that inherently maintains good indoor air quality

f. Adaptability for future changes and expansion – there needs to be flexibility in the way that the HVACR system can be operated to adapt to changing utility rates and structures in the future. Further, the HVACR systems at the zone level need to be flexible for changes in department layout and function, and technological changes. There are no known expansion plans for the facility.

Functional Uses

The functional uses of the ASHRAE Headquarters include those typical of an office building, plus several specific uses unique to non-profit organizations. The functional uses common to most user groups include:

a. Conference rooms - Adequate meeting space for the various groups is required for efficiency of activities and to simplify scheduling issues.

b. Offices - All user groups within the building require office space for their staff. The needs are a combination of private offices and open cubicle-style workstations.

c. Storage space - Lockable storage space is a necessity for each individual and each group within the building.

d. Reception / Waiting areas - Obvious entrances with defined waiting areas are needed by all groups to help improve the professional image of each group and to guide building visitors.

e. Break areas - Staff break areas that have preparation, storage, and eating areas is essential.

f. Library – A dedicated area for the organization and storage of documents published by the Society and related documents from industry. It shall also have a location for the storage of historical documents of importance to the Society.

g. Copier / Equipment space - Each group requires designated locations for office equipment such as printers, copiers, and fax machines.

h. Awards display area – Common area for the storage and display of awards and Society treasures.

In addition to the functional areas defined above, the building as a whole requires a variety of support areas to allow each group to operate efficiently. These support areas include:

i. Corridors - Corridors on each floor provide efficient movement throughout the building and between the building user areas. The corridors should be designed to prevent blind corners and collisions and be wide enough to allow carts from the loading area to pass.

j. Stairways and Elevators - The stairways and elevators provide efficient movement between the floors in the building. These features should be conveniently located for building egress and accessibility requirements.

k. Public Restrooms - Public restrooms are needed for use by any building occupant or visitor. The restrooms must be conveniently located, clearly marked, and accessible.

l. Custodial space - Closets or other designated custodial areas are needed on each floor to allow the janitorial staff to efficiently perform their duties without interruptions or inconveniences to other building staff.

m. Print room – Printing of all Society marketing materials, flyers, and internal documents.

n. Mail room – A mail room for the processing and distribution of mail for the Society.

o. Mechanical rooms - Space must be designated within the building to allow for installation of mechanical equipment. This space should be optimally located to allow for the simplest and most efficient mechanical design.

p. Parking – Adequate parking for employees and visitors that is safe and accessible during normal operating hours and after-hours activities.

q. Electrical / Communications space - Each floor of the building must contain adequate space for installation of electrical and communications equipment. These spaces must be located in coordination with the Communications department to ensure that all user technology and utility needs are achievable.

Certain user groups within ASHRAE Headquarters also have specific requirements for spaces not categorized above. Each of these spaces is listed below according to the appropriate user:

President's Office:

r. Private Restroom - A private restroom is required adjoining the President and Staff Executive offices.

Print Shop:

s. Loading dock - The loading dock area is needed near the Print Plant and Mail Room in order to support to all building areas.

Accounting:

t. Secure workroom – Accounting requires a secure workroom for the processing of all in-coming mail for the entry and documentation of receipts.

There is also the functional use consideration of the integration of systems to achieve all OPR. For the ASHRAE Headquarters, there shall be a single interface shall be used for the HVACR control, lighting control, emergency power control, uninterruptible power system control, and security systems.

Occupancy Requirements

The building is regularly occupied from 7 a.m. to 6 p.m., Monday through Friday, with public hours of 8 a.m. to 5 p.m. There is periodic extended occupancy during the week and throughout the weekends is required by individual staff members and for special events such as Society Committee meetings. The facility is closed for all Federal holidays.

The peak occupancy requirements for ASHRAE Headquarters are:

- 80 staff
- 25 normal visitor population
- 150 special-event visitor population

The occupancy schedule to be used to set up the control system is detailed in Table 1.

Table 1: Occupancy Schedule

Day of Week	State	Morning Warm-up	Occupied	Unoccupied	Special Event
Monday to Friday	On	6:00 a.m.	7:00 a.m.	6:00 p.m.	6:00 p.m.
	Off	7:00 a.m.	6:00 p.m.	6:00 a.m.	10:00 p.m.
Saturday	On	N/A	9:00 a.m.	1:00 p.m.	7:00 a.m.
	Off	N/A	1:00 p.m.	Midnight	6:00 p.m.
Sunday	On	N/A	N/A	Yes	7 a.m. – 6 p.m.
Holidays	Off	N/A	N/A	Yes	N/A

Occupant/space use requirements and schedules – an occupant of ASHRAE Headquarters is defined as anyone who is in the space more than 3 hours. The primary occupant requirements are:

a) Comfort is defined as:

i) Temperature – consistent temperature within the space and from space to space.

ii) Humidity – consistent humidity levels in the space to avoid a “sticky” feeling.

Comment: Note that many of these comfort items are not directly HVACR related. However, this is how the owner defines comfort and must not be altered if it goes beyond a mechanical definition.

iii) Adequate desk and storage space – sufficient desk space to handle several tasks at once and storage space for supplies and project files that is easily within reach.

iv) Noise – avoid distraction of noise from adjacent areas/cubicles and from equipment in or above/below the space.

v) Air Quality – no odors – air shall have a "fresh" feeling.

vi) Plenty of common space – there are open areas with flexibility in use to accommodate various functions and activities.

vii) Lighting – use of individual task lighting that is adjustable and directional.

viii) Controllability of total environment – ability to control local comfort of temperature, airflow, noise, and position (seat).

ix) No drafts – consistent airflow throughout the space with no "drafts" or "dead spots."

x) Good flooring – the flooring is aesthetically pleasing, highly durable, and comfortable to walk upon.

xi) No glare – there is no glare from lighting or outdoors on computer screens.

b) Interface with the operation and maintenance personnel – it is expected that the occupant will interface with the operation and maintenance staff through a telephone work order system, with operations and maintenance staff present during normal operating hours.

Health, hygiene, and indoor environment – the following are the known activities that generate pollutants in/near the facility, with possible impact on the HVACR system:

a) Poor circulation – build-up of pollutants due to a lack of air circulation.

b) Inappropriate use and maintenance of materials – materials emit pollutants or the maintenance of the materials has excessive pollutants.

c) Dumpster – the trash within the dumpster.

d) Dirty ventilation system – build-up of dust and dirt within the ventilation system (outdoor air intake).

e) Vehicles (loading docks) – combustion products from idling vehicles.

f) Cooking – odors, particulates, and smoke from cooking.

g) Pests – pests from outdoors.

h) Smoking – byproducts of smoking (butts and smoke).

i) Noise – noise from adjacent spaces and outdoors.

j) Printing plant – chemicals used in the printing plant.

k) Dirty carpets – build-up and re-outgasing of pollutants from carpets.

l) Cleaning – chemicals and materials utilized during cleaning.

m) Lavatories – bathroom byproducts.

n) Mildewed ceiling tiles – growth from water buildup on materials.

o) Dirty filters – allowing dust and dirt to bypass filtration.

p) Computers – heat, noise and chemicals.

q) Copiers/printers – heat, noise and chemicals.

r) Cologne/perfume – personal odors.

s) Refrigerators – spoiled foods and spills.

t) Microwaves – spills.

u) Mail room – dust from opening packages and processing equipment.

v) Dirty phones – build-up of dirt on phones from use.

Budget Considerations and Limitations

Budget constraints exist on all projects. For this project, the benefits of improvements must be weighed against their cost. The owner wants to achieve the highest quality facility at the lowest possible investment. Any cost effective opportunity to improve the quality of the system will be welcomed for review.

As in other quality management systems, achieving or increasing the level of quality is best accomplished by involving every worker on the project. This means that when anyone on the project identifies opportunities for improvement, or a potential problem, it should be brought to the immediate attention of the project manager or a member of the commissioning team. It may not be possible to incorporate every good idea on this project, but the knowledge gained will be beneficial to future projects. Potential problems that can be avoided are to everyone's benefit.

The approach to allocating resources for the HVACR systems is to examine life cycle costs, including capital investment, operating costs, maintenance costs, and employee productivity. The key values to be used are:

a) Life of HVACR systems = 25 years
b) Return on investment = 7%
c) Inflation rate = 3%
d) Productivity rate = $1,600/hour
e) Fuel escalation rate = 2%

$[X] of the project budget has been allocated for implementation of the Commissioning Process

Performance Criteria

The performance criteria upon which this project is being evaluated by the Commissioning Team are included in this section. Each performance criterion is verified during the Pre-Design, Design, Construction, and/or Occupancy & Operations phase(s) of the project. The performance criteria are categorized into the following groups:

- General
- Economic
- User Requirements
- Construction Process
- Operations

- Systems
- Assemblies

General

1) Quality requirements of materials and construction –the level of quality of the HVACR materials is defined by:
    a) Durability – high durability with resistance to damage by ambient conditions, users or operation and maintenance personnel.
    b) Time expectancy between failures – no equipment failures during the first five years of operation.
    c) Time expectancy between replacements – 25 years.
    d) Owner general expectations of quality of construction – above average.
2) Community requirements – the ASHRAE Headquarters is being located in a historical district: thus there are limitations on lines of sight to mechanical equipment. In addition, HVACR equipment noise needs to be 10 dB less than current code requirements.
3) Acoustical requirements – no noise generated from the HVAC system that results in distraction of the occupants, including central systems, ductwork, unitary units, and room air distribution.
4) Vibration – vibration from the HVACR components shall not be transmitted where it is felt by the occupants.
5) Seismic – the facility is not located in a seismic zone, so there are no special concerns relative to the HVACR systems.
6) Accessibility – the accessibility issues for the owner include:
    a) Occupants – system overrides shall be integrated with the zone temperature sensor and allow for after-hour system operation in 30 minute increments.
    b) Operations and maintenance staff – the maintenance space shall be 20% greater than manufacturer recommendations. Stairs shall be used (not vertical ladders) for access to major equipment. All gauges shall be clearly visible from floor level and all test ports, shut-off valves, and items required for maintenance shall be accessible by a 6-foot, 250 pound person.
7) Security – the facility shall be positively pressurized with any outside air intakes not accessible to the general public. The ductwork to the accounting workspace shall be impenetrable.
8) Aesthetics – there shall be no exposed ductwork in the occupied space. All exterior HVACR components shall be hidden when viewed from the property line at ground level.
9) Constructability – the maximum height of any truck delivery to the site is limited to 30 feet due to overhead power lines.
10) Communications – there shall be one communication system (backbone) throughout the entire facility, which the HVACR control system will use between its components.

11) Sustainability – a LEED™ Silver certification level is desired for this project. In pursuit of this certification, the following sustainability items are to be the focus:

a) Use of low energy system components – utilize high efficient components for installed and occupant items.

b) Build specific to the site – integrate site conditions to building layout and systems.

c) Accomplish research of real needs of project – develop comprehensive Owner's Project Requirements document.

d) Minimize adverse impact on the environment – utilize benchmarks for impact on the environment.

e) Involve all stakeholders – input is provided from all stakeholders and they are to be kept informed throughout the project.

f) Create real incentive – have real incentives for designers, contractors, and occupants for achieving a sustainable facility.

g) Achieve platinum instead of certification – have far reaching goals.

h) 2% of building energy use comes from renewable sources – purchase renewable power.

i) Use fixtures and equipment with water and energy conservation – use low water and energy fixtures.

j) Use of renewable resources (solar, wind, and geothermal) – use renewable resources on-site.

k) Daylighting and energy efficient lighting systems – design flexibility into the lighting system and maximize use of daylighting.

l) Ensure design of building minimizes energy loss – building envelope must have very good thermal properties.

m) Incorporate energy control measures (ECM's) – develop and accomplish analysis to integrate energy saving measures as part of design process.

n) Reuse materials – reuse materials when possible.

o) Do not compromise building quality with LEED™ – certification is not the goal, a more sustainable facility is.

p) Site selection – choose a site that is a brown field.

q) Establish and evaluate the options (LCC) – use a life cycle cost approach in evaluating options.

r) Produce less waste – minimize waste from construction and manufacturing.

s) Create awareness of stakeholders – educate team members about sustainable features.

t) Use less toxic materials – do not use any toxic substances in the facility.

u) Set maximum amount of energy use of building per year – define target for energy use per year – recommend 15% below standards.

v) Improve indoor air quality – improve indoor air quality to result in improved worker productivity.

w) Use proper orientation of buildings on site – orientate site to maximize natural daylighting and minimize cooling and heating loads.

x) Install automatic controls on mechanical systems – use of well designed controls.

y) Conserve resources and energy – minimize materials required and the energy used to create materials.

z) Locate building on public transit routes – locate building for easy access to mass transportation and pedestrian paths.

Economic

12) Benchmark

a) Cost of Operating – the cost to operate the system, including utilities, manpower and materials.

b) Lowest lifecycle cost – the lowest 30-year life cycle cost options are adopted and implemented on the project.

c) Cost of Energy – the unit cost of energy, including taxes and demand charges.

d) Lowest energy use compared to surrounding facilities – compare the energy use to surrounding facilities or similar benchmark (e.g., Energy Star™).

13) Energy efficiency

a) Better than ASHRAE Standard 90.1 – building performs 20% better than requirements in ASHRAE Standard 90.1 [current version].

b) BTU/ ft^2/year – the energy use for heating, cooling, and plug loads per year on a unit area basis.

c) Energy Star™ Rating – compare building operation against other similar buildings, corrected for location, utilizing the Energy Star™ rating system.

d) 5% reduction each year for first 5 years – there is a reduction in energy use and cost for the first five years of operation through optimization and focus on energy efficiency.

e) Flexibility in system to changes in utility rates – provide a system that has flexible operational strategies that can adapt to changes in utility rate structures and values.

f) $/ ft^2/year – the dollars spent on utilities per year on a unit area basis.

g) Number of energy savings ideas submitted – the number of energy savings ideas that are generated by the building occupants, taking advantage of an on-going understanding and focus on energy efficiency.

h) Avoid system degradation – avoid degradation of systems that leads to reduced energy efficiency.

i) # hot/cold calls per year – track the number of annual comfort complaints to verify that non-energy criteria are not compromised by focusing solely on energy efficiency.

j) Use of low-energy office equipment – plug loads to be reduced each year through acquisition of more energy efficient office equipment.

k) Actual compared to budget – compare the actual to the budget to verify assumptions and identify opportunities to improve.

User Requirements

14) User requirements – The user's primary requirements for HVACR systems are:

a) Reception area is not drafty.

b) Reception area has ergonomic chairs.

c) Signage enables quickly finding destination.

> Note: while items 13 b & c are not HVAC&R related, these examples are included as they were the user's definition of comfort. Therefore, other discipline requirements will often be identified during the Owner's Project Requirements workshop and should be documented appropriately.

Construction Process

15) The training needs to contain a variety of sessions that operations and maintenance personnel and building occupants will attend. The sessions shall be digitally recorded and processed for long-term availability to changing staff. The following defines what is considered successful training:

a) Commissioning Authority gives OPR and the architect gives a Basis of Design overview for users and O&M staff. Prior to any contractor training, the Commissioning Authority provides an overview of the OPR to provide a baseline of what should be expected for a successful facility. The architect then provides an overview of the Basis of Design to explain how they achieved the OPR. Both the facility users and O&M staff need to be involved.

b) O&M (for users and O&M staff) training for building systems (fire alarms, emergency power, lighting controls, security and switchboards) – different levels of training for both the users and O&M staff.

c) HVAC building automation system – detailed instruction on use of the building automation system in troubleshooting and fixing problems.

d) Training with an operational plan – provide training around an operational management plan on how the building will actually be managed to provide direct context to the training.

e) Safety training on building systems for O&M – include safety training for the O&M staff relative to such items as confined spaces, handling of chemicals, emergency response, etc.

f) Energy systems along with related mechanical system – training on the interaction of the mechanical systems relative to the energy efficiency of the facility.

g) Training for O&M staff by space areas – specific attention paid to the unique needs of each area, including contact person introduction and communication procedures.

h) Component training – training provided for specific components relative to preventative maintenance procedures and interaction with its connected systems.

i) Class on the ADA requirements (custodians and O&M) – a session on the ADA features of the facility, what must be accomplished to maintain these features, and any unique needs of any of the staff.

j) Training for contractors on installing special systems/equipment – provide training by the manufacturer on the proper installation and start-up of systems and equipment.

k) Troubleshooting on building systems – a session on typical problems that will likely be encountered in operating the facility and guidance (matrix) on how to troubleshoot and resolve the problem.

l) Scheduled construction walkthroughs – periodic guided walkthroughs of the facility during construction, allowing the O&M staff to ask questions of the design professionals and contractors so that they can learn the systems as they are being constructed.

16) Warranty Requirements – all HVAC&R warranties are to begin at substantial completion, regardless of when the component is delivered, installed, or put into service. For small components (those under $100,000 in first cost) the warranty shall be for one year. For large components (those over or equal to $100,000 in first cost) the warranty shall be for five years and include all labor costs, parts, and consumables. Any item required to be accomplished by the operations and maintenance personnel must be clearly documented and provided prior to the start of warranties.

17) Equipment and system maintainability expectations – all equipment must be easily accessible, locatable, and clearly labeled. The system documentation must be accurate and consistent with actual installed components and operation. The requirements for the system documentation include:

a) As-builts are accurate (include TAB) – the record documentation has been verified to be accurate and is provided in a usable format.

b) Trouble shooting – a troubleshooting matrix is provided for typical issues anticipated for the system relative to the OPR.

c) Accurate start-up and shut-down procedures – easy to find and follow start-up and shut-down procedures are available to the O&M staff.

d) Detailed how-to manuals – manuals provide clear and concise how-to guidance.

e) Completed accurate information – all documentation is accurate and complete.

f) Detailed sequence of operation – detailed sequence of operations on any low voltage system with software logic diagrams.

g) Video training for new personnel (various for different levels of knowledge) – DVD, indexed and edited recording of training for easy access to O&M staff when required.

h) Technical support numbers – easily located technical support telephone numbers and contact information.

i) Detailed maintenance schedule (template for spreadsheet) – simple maintenance schedule matrix detailing what is required when, and why.

j) Valve chart – a chart that details where each valve is located, its number and its operation.

k) List of common errors and how to fix them – summary of the errors/issues found during the process and how to resolve them so that the OPR is maintained.

l) A list of where parts are available – the parts list, suppliers, and contacts.

m) How system is intended to work and to be used – review of the OPR/BoD prior to any other training to provide context and content to the trainees

18) Adaptability – the HVACR systems shall be flexible to future changes without the need for additional investment or outside resources.

Operations

19) Training requirements for owner's personnel – the owner will be utilizing in-house operations and maintenance resources. These personnel will have between 10 and 25 years experience and it is assumed they are conversant in basic computer maintenance techniques and are computer proficient.

20) Warranty – prior to any changes to components, the warranty requirements summary will be reviewed to avoid voiding of warranties.

21) Benchmarking Requirements – the following are the key benchmarks for the HVACR system:

a) Warranty issues – the number of warranty issues that arise during the first year of operation.

b) Industry standards – the percentage of industry standards that are exceeded.

c) Professional Standards – the percentage of best practice professional standards that are adopted.

d) History of similar systems – comparison of operations from similar systems in nearby facilities.

e) Longevity – the mean time between failure and estimated longevity of the facility.

f) Number of occupant complaints – the number of occupant complaints tracked by type, time, and person.

g) <1.5°F variation in occupied space – maintaining consistent temperature distribution within a room.

h) Comparison of old/new units – comparison with benchmarks of system operation in the existing facility.

i) Availability of parts – the time it takes to receive a part from the time when its need was identified.

j) No punch list items – no punch list items remain upon occupancy of the facility.

k) Air quality measurement (CO_2, etc.) – measure and track air quality measurements, such as the difference in carbon dioxide concentration in the outdoor and space air.

l) Occupants not aware of physical conditions – indoor environment enhances employee's work.

m) Happy contractors – contractors do not complain about project.

n) Adaptability to future changes – the systems are adjustable to changes in use and function within the facility.

Note: other benchmark items could include number of work orders, average response and resolution times, system downtimes, energy and maintenance costs, measure of system degradation, and percentage of preventative maintenance items accomplished.

22) Operations and maintenance criteria – the main operations and maintenance criteria is that the budget is expected to be $[X]/ ft^2 utilizing contracted personnel, with a maximum complaint rate of [X]/week. It is expected that the operations and maintenance personnel will follow the manufacturer's recommended frequencies and activities and that they are able to easily maintain the system documentation to include changes to components and systems.

23) Energy Efficiency – on-going commissioning of the systems is intended to reduce energy by 5% each year for the first five years of operation.

24) Adaptability – any changes to the space or system will be evaluated against the current OPR and BoD to verify the system can meet the new requirements and any changes to the systems are properly documented.

Systems

25) System Integrity – there are no special concerns relative to the HVACR systems.

26) Energy Efficiency – there are no special concerns relative to the HVACR systems.

Note: as the HVACR components are part of a system, the performance criteria for systems have been covered above. If the performance criteria were focused upon assemblies, such as envelopes, then the assemblies would likely be empty and something in the systems.

Assemblies

27) Assembly Integrity – the envelope moisture and air permeability must match or exceed the BoD for the HVACR systems to achieve their OPR.

28) Energy Efficiency – the envelope thermal performance must match or exceed the BoD for the HVACR systems to achieve their OPR.

Owner's Project Requirements Version History

The changes made to this OPR document throughout the Pre-Design, Design, Construction, and Occupancy and Operations Phases are summarized in the following table. Tracking of this information is critical in that it enables future operators and design professionals an understanding of the trade-offs made during the project and the resulting impact on the facility and achievement of the OPR.

Change #	Original OPR	New OPR	Reason for Change	Approved By	Date Approved
1	Items under "Performance Criteria – Systems" were the same as those under "Performance Criteria – Economic – Energy Efficiency"	"Performance Criteria – Systems – Energy Efficiency" was changed to "there are no special concerns relative to the HVACR systems"	Remove redundancy	Bill Bale (owner)	8/5/4
2					
3					

OPR Workshop Responses

An OPR Workshop was convened on August 20, 2004. This section contains the results of the workshop. The attendees of the OPR Workshop were:

Attendee	Representing	Phone	E-mail Address
[insert workshop attendees]			

The questions answered during the workshop were:

1. What areas are required for a functional facility? *This question gets the attendees to define the areas of the facility that are required for functionality (e.g., classrooms, restrooms, administration, etc. for an elementary school).*

2. List conditions important to your comfort in an ideal building. *This question gets the attendees to define what comfort is on their terms and provides the design engineer with information they traditionally do not get.*

3. What activities generate pollutants in this building? *This question provides an understanding of the activities that are perceived to produce pollutants. The benefit is that the architect and engineer can determine how to avoid health and comfort problems through design or process changes.*

4. How do we make this facility more sustainable? *This question provides a clear understanding of how the owner defines sustainability. The*

responses from this question can then be applied to typical green rating systems (e.g., LEED™ and BREAM™).

5. How do you define energy efficiency? *This question is for the O&M staff and is intended to determine how they define the energy efficiency of the building and what level of efficiency is acceptable.*

6. How will you benchmark system operation? *This question is for the O&M staff and provides information on how they will measure the performance of the building.*

7. What documentation is required to properly operate and maintain facilities? *This question is for the O&M staff and provides input on what documentation they require and how they will use it.*

8. What are your training requirements? *This question is for the O&M staff, and sometimes for the occupants, to understand what is needed to understand the systems and building.*

9. What problems with previous projects should be avoided? *This question is intended to understand what problems have occurred on previous projects so that we can avoid them on this project.*

10. What must be accomplished for a successful project? *This question is typically not asked and often results in misunderstandings. By understanding how the team is going to evaluate the success of the project, the designers will be able to meet these expectations.*

The following tables contain the ranked responses and clarifications from the OPR Workshop.

Question 1: What Areas are Required for a Functional Facility?

Response #	Responses	Clarification	Score
A-2	Conference rooms	Adequate meeting space for the various groups is required for efficiency of activities and to simplify scheduling issues.	27
A-3	Offices	All user groups within the building require office space for their staffs. The needs are a combination of private offices and open cubicle-style workstations.	25
A-4	Restrooms	Restrooms are needed for use by any building occupant or visitor. The restrooms must be conveniently located, clearly marked, and accessible.	14
A-1	Storage space (also 10)	Lockable storage space is a necessity for each individual and each group within the building.	13
A-12	Reception/waiting areas	Obvious entrances with defined waiting areas are needed by all groups to help improve the professional image of each group and to guide building visitors.	12
A-11	Break areas (also 21)	Areas that have preparation, storage, and eating areas are essential.	9
A-26	Library (also 43)	A dedicated area for the organization and storage of documents published by the Society and related documents from industry.	7
A-25	Custodial space	Closets or other designated custodial areas are needed on each floor to allow the janitorial staff to efficiently perform their duties without interruptions or inconveniences to other building staff.	6
A-8	Mechanical rooms (also 24 & 36)	Space must be designated within the building to allow for installation of mechanical equipment. This space should be optimally located to allow for the simplest and most efficient mechanical design.	5
A-9	Size of workspace	The individual workspace is sized to the activities to be accomplished.	5
A-15	Copier/equipment space	Each group requires designated locations for office equipment such as printers, copiers, and fax machines.	5
A-5	Parking	Adequate parking for employees and visitors that is safe and accessible during normal operating hours and after-hours activities.	4
A-6	Loading dock	The loading dock area is needed near the Print Plant and Mail Room to provide support to all building areas.	4
A-17	Electrical/communications spaces (also 33)	Each floor of the building must contain adequate space for installation of electrical and communications equipment. These spaces must be located in coordination with the Communications department to ensure that all user technology and utility needs are achievable.	4
A-39	Corridors	Corridors on each floor provide efficient movement throughout the building and between the building user areas. The corridors should be designed to prevent blind corners and collisions, and be wide enough to allow carts from the loading area to pass.	4
A-7	Control room	A room to house the control system for the mechanical, lighting, fire and security systems.	3
A-31	Accounting secure workroom	Accounting requires a secure workroom for the processing of all in-coming mail for the entry and documentation of receipts.	3
A-35	Stairs and elevators	The stairways and elevators provide efficient movement between the floors in the building. These features should be conveniently located for building egress and accessibility requirements.	3
A-30	Recyclable materials storage area	Specific areas for the collection and storage of recycled waste to minimize waste that is sent to the garbage dump.	2
A-44	Landscaping	Pleasant landscaping that utilizes local vegetation requiring minimal water and maintenance.	2
A-16	Print room	Printing of all Society marketing materials, flyers, and internal documents.	1

Response #	Responses	Clarification	Score
A-18	Daycare center	Daycare would be provided for children from toddlers through 5 years, and after school for ages 5 through 10.	1
A-29	Rooftop garden	Break area on the roof with landscaping and shaded sitting areas.	1
A-32	Atrium/plant area	An area where plants and natural daylighting is prevalent to help reduce space pollutants.	1
A-45	Dumpster	A dumpster location that is easily accessible and does not compromise the indoor air quality.	1
A-10	Office supply storage (see 1)	Centralized locations for office supplies.	0
A-13	Access areas in ceiling	Space is allocated to access components that require periodic maintenance.	0
A-14	President's private restroom	A private restroom located adjacent to the President's office for their use.	0
A-19	Exercise room	An exercise area for employees with free weights, stationary bicycles, treadmills, and gym system.	0
A-20	Smoking area	A designated area (internal or external of building) for smoking.	0
A-21	Employee kitchen (see 11)	A kitchen with refrigerator/freezer, microwave oven, sink, and vending machines.	0
A-22	Awards display area	Common area for the storage and display of awards and Society treasures.	0
A-23	Mail room	A mail room for the processing and distribution of mail for the Society.	0
A-24	Chiller/boiler room (see 8)	A separate room to house the chiller and boiler (code may require further separation).	0
A-27	Bicycle parking area	A designated area for bicycle parking and storage.	0
A-28	Employee shower	Showers and locker rooms for employees' use (specifically for those who bicycle to work and utilize the exercise room).	0
A-33	Telecommunications room (see 17)	A separate room for the telecommunication systems.	0
A-34	Flexible spaces	Flexible spaces for change of use over time and for multiple uses throughout a day/week.	0
A-36	Mechanical shafts (see 8)	Space for mechanical shafts is allocated.	0
A-37	Balconies	Balconies are provided for easy access to the outdoors.	0
A-38	Storm retention/bio-swells	Eliminate runoff from impervious surfaces.	0
A-40	Receiving room	A transition room between the loading dock and the final location of receivables.	0
A-41	Outside break area	An outside area for breaks, with shading and tables.	0
A-42	Basketball court	A 1/2 court basketball court in the parking lot.	0
A-43	Historical documents area (see 26)	A location for the storage of historical documents of importance to the Society.	0

Question 2: List Conditions Important to Your Comfort in an Ideal Building?

Response #	Responses	Clarification	Score
B-1	Temperature	Consistent temperature within the occupied space and between spaces.	40
B-2	Humidity (also 13)	Space humidity is maintained at a consistent level within the space to avoid degradation of the indoor air quality.	26
B-35	Adequate desk and storage space	The size of the desk and local storage space is tailored towards the tasks to be accomplished.	15
B-4	Noise	Occupants are not disturbed by noise from an adjacent area, outdoors, or from systems within the building.	13
B-8	Air quality	There is no dust in the space and the air is perceived as fresh.	12
B-21	No odors	There are no objectionable odors from space activities, personnel, or from outdoors.	11
B-23	Plenty of common space	There are open areas with flexibility in use to accommodate various functions and activities.	9
B-5	Lighting	Consistent lighting levels for the tasks to be accomplished, providing various levels and types of lighting.	7
B-24	Controllability of total environment	Individuals have control over their surrounding conditions, including temperature, lighting, and noise.	7
B-3	Control over temperature	Centralized control over the space temperatures to minimize contractor site visits.	5
B-10	No drafts	The air velocity in the space varies little to avoid perception of changes in velocity within a space.	5
B-29	Good flooring	The flooring is aesthetically pleasing, highly durable, and comfortable to walk upon.	4
B-39	No glare	There is no glare from lighting or outdoors on computer screens.	3
B-17	Window with a view (also 25)	Every occupant in open office spaces shall have a view of the outdoors and access to a window.	2
B-36	Safe workplace	The workplace is inherently designed and constructed to be safe, including a secure feeling from parking lot to office.	2
B-38	Clean working environment	Working areas are uncluttered, dust free, and have a professional appearance at all times.	2
B-15	Privacy in work areas	Ability not to be disturbed in workspace from outside noise, phone calls, etc.	1
B-34	Communication tools availability	Simple access to communication tools for interfacing with other staff, Society members, and visitors. This includes internet, phones, faxes, copiers, and wireless access.	1
B-6	Amount of windows	There is significant window area while avoiding introduction of direct solar load to the space.	0
B-7	Space relationships	Spaces are organized and laid out in a logical arrangement from a functional and organizational matter for both staff and Society members (visitors).	0
B-9	Comfortable chairs in break room	There are comfortable, easily cleaned chairs in the break room, where personnel gather for as long as 45 minutes.	0
B-11	Good exhaust in toilet	Bathroom odor shall not be noticeable within the bathroom or outside of the bathroom.	0
B-12	Airflow	The air flows from clean areas to dirty areas.	0
B-13	No sticky feeling (see 2)	The occupied space does not have a sticky feeling from high humidity.	0
B-14	Colors/textures/surroundings	There needs to be a variety of colors, textures and surroundings to provide a warm feel to the facility (non-institutional)	0
B-16	Smoking area conditioned	The smoking area is conditioned and designed to avoid indoor air quality issues with surrounding areas.	0
B-18	Natural lighting	Maximal use of daylighting to minimize the need for artificial lighting and	0

Response #	Responses	Clarification	Score
		air-conditioning load.	
B-19	Outside air (adequate)	The outdoor air is adequate to maintain good indoor air quality.	0
B-20	Drinking water	Filtered drinking water is easily accessible.	0
B-22	Work place size fitting of status	The size of workplace is proportional to the management position.	0
B-25	Pleasing exterior views (see 17)	The view from the window shall be pleasant.	0
B-26	Ceiling heights	The ceiling height shall provide for an open feeling and avoid making spaces claustrophobic.	0
B-27	Interior materials	The interior materials shall be durable and easy to maintain.	0
B-28	Line of sight to office assistant	Managers shall have a line of sight to their assistants.	0
B-30	No one in line of sight	No one is in line of sight of one another to ensure privacy.	0
B-31	Clear means of egress	Egress from any location is easy to understand and reach.	0
B-32	Parking space	There are accessible parking spaces for every staff member and expected visitors.	0
B-33	Elevator location	Vertical transport shall be located for ease of access and for all activities expected for its use.	0
B-37	Standby cooling and power	Facility has little downtime and can be operational during adverse weather events that are typical for the area.	0

Question 3: What activities generate pollutants in this building?

Response #	Responses	Clarification	Score
C-2	Poor circulation	Build-up of pollutants due to a lack of air circulation.	22
C-21	Inappropriate use and maintenance of materials	Materials emit pollutants or the maintenance of the materials produces excessive pollutants.	15
C-6	Dumpster	The trash within the dumpster.	10
C-13	Dirty ventilation system	Build-up of dust and dirt within the ventilation system (outdoor air intake).	10
C-18	Vehicles (loading docks)	Combustion products from idling vehicles.	10
C-7	Cooking	Odors, particulates, and smoke from cooking.	7
C-22	Pests	Pests from outdoors.	7
C-4	Smoking	Byproducts of smoking (butts and smoke).	5
C-5	Noise	Noise from adjacent spaces and outdoors.	5
C-16	Printing plant	Chemicals used in the printing plant.	4
C-1	Dirty carpets	Build-up and re-outgasing of pollutants from carpets.	2
C-8	Cleaning	Chemicals and materials utilized during cleaning.	2
C-11	Lavatories	Bathroom byproducts.	2
C-3	Mildewed ceiling tiles	Growth from water build-up on materials.	1
C-9	Dirty filters	Allowing dust and dirt to bypass filtration.	1
C-10	Computers	Heat, noise and chemicals.	1
C-19	Copiers/printers	Heat, noise and chemicals.	1
C-12	Cologne/perfume	Personal odors.	0
C-14	Refrigerators	Spoiled foods and spills.	0
C-15	Microwaves	Spills.	0
C-17	Mail room	Dust from opening packages and from processing equipment.	0
C-20	Dirty phones	Build-up of dirt on phones from use.	0

Question 4: How do we make this facility more sustainable?

Response #	Responses	Clarification	Score
D-20	Adopt an aggressive plan to use the USGBC guidelines	Aggressively utilize USGBC guidelines and best of practice items.	19
D-16	Use of low energy system components	Utilize highly efficient components for building systems.	18
D-48	Build specific to the site	Integrate site conditions to building layout and systems.	16
D-17	Accomplish research of real needs of project (also 28)	Develop comprehensive Owner's Project Requirements document.	14
D-1	Minimize adverse impact on the environment	Utilize benchmarks for impact on the environment.	12
D-13	Involve all stakeholders (also 42)	Input is provided from all stakeholders and they are kept informed throughout the project.	10
D-6	Create real incentive	Have real incentives for designers, contractors, and occupants for achieving a sustainable facility.	9
D-36	Require owners to achieve platinum instead of certification	Have far-reaching goals.	8
D-45	2% of building energy use comes from renewable sources	Purchase renewable power.	8
D-2	Use fixtures and equipment with water and energy conservation (also 26)	Use low water and low-energy fixtures.	7
D-15	Use of renewable resources (solar, wind, and geothermal)	Use renewable resources on-site.	7
D-22	Daylighting and energy efficient lighting systems	Provide flexibility in lighting system and maximize use of daylighting.	7
D-23	Use sustainable materials (see 10)	Maximize use of materials with recycled content and renewable components.	7
D-41	Ensure design of building minimizes energy loss	Building envelope has very good thermal properties.	7
D-7	Incorporate energy control measures (ECM's)	Develop and accomplish analysis to integrate energy saving measures as part of design process.	6
D-3	Establish a separate budget line item for LEED™ & CxP	Separate budgets and LEED™ and Commissioning Process activities with separate contracts with independent contractors.	5
D-14	Accomplish CxP and enable design professionals	Fully implement and integrate the Commissioning Process and enable design professionals to truly design the facility.	5
D-18	Reuse materials (also 40)	Reuse materials when possible.	5
D-34	Do not compromise building quality with LEED™	Stress that certification is not the goal, a more sustainable facility is.	5
D-8	Site selection - use brown in-fills	Choose a site that is a brown field.	4
D-12	Establish and evaluate the options (LCC)	Use a life cycle cost approach in evaluating options.	4
D-19	Produce less waste	Minimize waste from construction and manufacturing.	4
D-25	Create awareness of stakeholders	Educate team members about sustainable features.	4
D-27	Use less toxic materials	Do not use any toxic substances in the facility.	4
D-32	Set maximum amount of energy use of building per year	Define target for energy use per year – recommend 15% below standards.	3
D-4	Improve indoor air quality	Improve indoor air quality to result in improved worker productivity.	2
D-9	Use proper orientation of buildings on site	Orientate site to maximize natural daylighting and minimize cooling and heating loads.	2

Response #	Responses	Clarification	Score
D-24	Install automatic controls on mechanical systems	Use of good controls.	2
D-30	Conserve resources and energy	Minimize materials required and the energy used to create materials.	2
D-35	Locate building on public transit routes (also 39 and 47)	Locate building for easy access to mass transportation and pedestrian paths.	2
D-21	Use natural landscaping	Landscaping that is indigenous to the area and that requires minimal maintenance and irrigation.	1
D-29	Size heating/cooling equipment to 98% of loads	Minimize size of mechanical systems, understanding there will be some uncomfortable periods.	1
D-5	Minimize pavements	Minimize impervious surfaces.	0
D-10	Use more recycled building products (also 23 and 31)	Maximize use of recycled content.	0
D-11	Use longer lasting materials	Design facility for 100 years.	0
D-26	Use low water fixtures (see 2)	Use low and no-water bathroom fixtures.	0
D-28	Include contractor during preparation of OPR (see 17)		0
D-31	Always use environmental friendly products (see 10)		0
D-33	Purchase/acquire LEED™ game	Educate team members through use of LEED™ game.	0
D-37	Upgrade all utility supply systems	Ensure utility supply systems are sized appropriately to handle current and future loads so that owner does not have to replace items in future.	0
D-38	Utilize green roofs	Install a living roof.	0
D-39	Increase pedestrian ways (see 35)		0
D-40	Reuse materials from buildings scheduled for demolition (see 18)		0
D-42	Establish and incorporate buy-in of organizational entities (see 13)		0
D-43	Exceed all codes	Exceed minimums.	0
D-44	Construct building for future expansion and changes to minimize use of materials		0
D-46	Data file of lessons learned	Use data for continuous improvement and application to future projects – create and publish a case study.	0
D-47	Site building with access to infrastructure (see 35)		0

Question 5: How do you define energy efficiency?

Response #	Responses	Clarification	Score
E-3	Better than ASHRAE Standard 90.1	Building performs 20% better than requirements in ASHRAE Standard 90.1 [current version].	43
E-5	BTU/ ft^2/year	The energy use for heating, cooling, and plug loads per year on a unit area basis.	38
E-2	Energy Star™ Rating (also 9)	Compare building operation against that of similar buildings, corrected for location, utilizing the Energy Star™ rating system.	32
E-4	5% reduction each year for first 5 years	There is a reduction in energy use and cost for the first five years of operation through optimization and focus on energy efficiency.	24
E-7	Flexibility in system to changes in utility rates	Having a system that has flexible operational strategies that can adapt to changes in utility rate structures and values.	23
E-1	$/$ft^2$/year	The dollars spent on utilities per year on a unit area basis.	12
E-6	Number of energy savings ideas submitted	The number of energy savings ideas that are generated by the building occupants – indicating an on-going understanding and focus on energy efficiency.	5
E-8	Avoid system degradation	Avoid degradation of systems that leads to reduced energy efficiency.	4
E-10	# hot/cold calls per year	Track the number of annual comfort complaints to verify that non-energy criteria are not compromised by focusing solely on energy efficiency.	3
E-11	Use of low energy office equipment	Plug loads to be reduced each year through acquisition of more energy efficient office equipment.	1
E-12	Actual compared to budget	Compare the actual to the budget to verify assumptions and identify opportunities to improve.	1
E-9	BTU/ ft^2/CDD/year (see 2)	Correct energy use value relative to the number of cooling degree days in order to be able to more accurately compare values from year to year.	0

Question 6: How will you benchmark system operation?

Response #	Responses	Clarification	Score
F-4	Cost of Operating	The cost to operate the system, including utilities, manpower and materials.	32
F-6	Warranty issues	The number of warranty issues that arise during the first year of operation.	21
F-10	Industry standards	The percentage of industry standards that are exceeded.	14
F-8	Professional Standards	The percentage of best-practice professional standards that are adopted.	9
F-1	History of similar systems	Comparison of operations from similar systems in nearby facilities.	8
F-2	Longevity	The mean time between system failure and the estimated longevity of the facility.	6
F-17	Number of occupant complaints	The number of occupant complaints tracked by type, time, and person.	6
F-4	<1.5°F variation in occupied space	Maintaining consistent temperature distribution within a room.	5
F-19	Lowest lifecycle cost	The lowest 30-year life cycle cost options are adopted and implemented on the project.	5
F-11	Comparison of old/new units	Comparison with benchmarks of system operation in the existing facility.	4
F-7	Cost of Energy	The unit cost of energy, including taxes and demand charges.	3
F-16	Availability of parts	The time it takes to receive a part from the time when its need was identified.	3
F-18	Lowest energy use compared to surrounding facilities	Compare the energy use to surrounding facilities or similar benchmark (e.g., Energy Star™).	3
F-20	No punchlist	No punchlist items remain upon occupancy of the facility.	3
F-23	Air quality measurement (CO_2, etc.)	Measure and track air quality measurements, such as the difference in carbon dioxide concentration in the outdoor and space air.	3
F-14	Occupants not aware of physical conditions	Indoor environment enhances employees work.	2
F-25	Happy contractors	Contractors do not complain about project.	2
F-5	Adaptability to future changes	The systems are adjustable to changes in use and function within the facility.	1
F-3	Classroom learning environment	The facility is a learning environment for the members, visitors, and community.	0
F-9	No callbacks for at least 5 years	Outside contractors are not required during the first 5 years of operation.	0
F-12	Days missed by workers	The number of days missed (sick days) by workers per year.	0
F-13	Verify specs	Verification that the project specifications have been achieved.	0
F-15	Short response time of system to changes in environment	The system responds quickly to changes in the outdoor or indoor conditions to maintain system's energy efficiently.	0
F-21	Visitor complaints	Track the number of visitor complaints and address any that have been documented.	0
F-22	System down time	The number of hours per year the system does not operate when required or does not maintain space conditions.	0
F-24	Able to operate parts of building without affecting others	There is flexibility in operation to maintain conditions in one area of the building that is occupied off hours.	0

Question 7: What documentation is required to properly operate and maintain facilities?

Response #	Responses	Clarification	Score
G-1	As-builts are accurate (include TAB)	The record documentation has been verified to be accurate and is provided in a usable format.	24
G-7	Trouble shooting (also 11)	A troubleshooting matrix is provided for typical problems anticipated for the system relative to the OPR.	17
G-13	Accurate start-up and shut-down procedures	Easy to find and follow start-up and shut-down procedures are available to the O&M staff.	15
G-3	Detailed how to manuals	Manuals provide clear and concise how-to guidance.	14
G-2	Completed accurate information	All documentation is accurate and complete.	10
G-5	Detailed sequence of operation	Detailed sequence of operations on any low voltage system with software logic diagrams.	9
G-10	Video training for new personnel (various for different levels of knowledge)	DVD indexed and edited recording of training for easy access to O&M staff when required.	8
G-15	Technical support numbers	Easily located technical support telephone numbers and contact information.	8
G-12	Detailed maintenance schedule (template for spreadsheet)	Simple maintenance schedule matrix detailing what is required, when, and why.	6
G-17	Valve chart	A chart that details where each valve is located, its number and its operation.	3
G-18	List of common errors and how to fix them	Summary of the errors/issues found during the process and how to resolve them so that the OPR is maintained.	3
G-6	A list of where parts are available	The parts list with suppliers and contacts identified	1
G-8	How system is intended to work/be used	Review of the OPR/BoD prior to any other training to provide context and content to the trainees	1
G-4	Operating capacities of the units	Evaluation of O&M staff capabilities and what they must accomplish to achieve success.	0
G-9	Diskettes/CDs	All information provided in electronic format on DVD's.	0
G-11	What-if manual (see 7)		0
G-14	Dated guarantee warranty for parts	Single date for start of warranties. Also understand what must be accomplished by O&M staff to maintain the warranty.	0
G-16	Ability to update manual	The ability to update documentation and understand process versus activity.	0
G-19	Windows oriented table of contents/index, easy to use	Electronic version with Windows interface. Must be able to quickly locate and print out the actual requirements.	0
G-20	Lock out tag/out procedure (safety)	Clear training and tools in place to lock out and tag out system components.	0
G-21	Integration with other systems and buildings (standard software)	Integration with other systems.	0
G-22	System interaction	Interaction of the system to achieve OPR.	0
G-23	Manufacturer's information	Clear, tailored manufacturer's instructions.	0
G-24	Easily updatable	Material is easily updated to document changes and handle new requirements.	0

Question 8: What are your training requirements?

Response #	Responses	Clarification	Score
H-12	Commissioning Authority gives OPR and the architect gives a Basis of Design overview for users and O&M staff (also 8)	Prior to any contractor training, the Commissioning Authority provides an overview of the OPR to provide a baseline of what should be expected for a successful facility. The architect then provides an overview of the Basis of Design to explain how they achieved the OPR. Both the facility users and O&M staff need to be involved.	27
H-1	O&M (for users and O&M staff) training for building systems (fire alarms, emergency power, lighting controls, security and switchboards) (also 6)	Different levels of training for both the users and O&M staff.	26
H-9	HVAC building automation system	Detailed instruction on the use of the building automation system in troubleshooting and fixing problems.	15
H-13	Training with an operational plan (focused) - put needs and intents together	Provide training around an operational management plan on how the building will actually be managed to provide direct context to the training.	15
H-2	Safety training on building systems for O&M	Include safety training for the O&M staff relative to such items as confined spaces, handling of chemicals, emergency response, etc.	14
H-5	Energy systems along with related mechanical system	Training on the interaction of the mechanical systems relative to the energy efficiency of the facility.	8
H-3	Training for O&M staff by space areas	Specific attention paid to the unique needs of each area, including contact person introduction and communication procedures.	7
H-7	Component training	Training provided for specific components relative to preventative maintenance procedures and interaction with its connected systems.	6
H-4	Class on the ADA requirements (custodians and O&M)	A session on the ADA features of the facility, what must be accomplished to maintain these features, and any unique needs of any of the staff.	5
H-10	Training for contractors on installing special systems/equipment	Provide training by the manufacturer on the proper installation and start-up of systems and equipment.	5
H-11	Troubleshooting on building systems	A session on typical problems that will likely be encountered in operating the facility and guidance (matrix) on how to troubleshoot and resolve the problems.	4
H-14	Scheduled construction walkthroughs	Periodic guided walkthroughs of the facility during construction where the O&M staff can ask questions of the design professionals and contractors so that they can become familiar with the systems as they are being constructed.	3
H-6	Systems training (users and O&M) (see 1)		0
H-8	Training of users on purpose/intent of building systems to have vocabulary to communicate with O&M (see 12)		0

Question 9: What Problems with Previous Projects should be avoided?

Response #	Responses	Clarification	Score
I-1	Lack of consistency from area to area	There is lack of good temperature and airflow from space to space.	33
I-15	Tampering with room thermostats - operation misunderstood by building users	Facility users do not understand system operation and inadvertently create comfort problems through tampering with the room thermostats.	16
I-6	Sound travels - acoustic problems	Excessive noise from adjacent areas, outdoors, and mechanical systems.	11
I-13	Roof leaks	Water leakage through the roof resulted in indoor air quality problems and aesthetic concerns.	10
I-12	Sequence of operation for boilers not proper	The operating sequence for the hot water boilers was complicated and resulted in inefficient operations.	8
I-8	Stuffiness	The space was stuffy (may have been hot or lack of air movement).	7
I-3	Computer BAS not friendly	The building automation system was never fully operational and it was difficult to utilize easily on a daily basis.	6
I-5	Hallways too narrow	The corridors were too narrow to allow two carts to easily pass or to permit a conversation to take place outside of the office area.	6
I-9	Inadequate electrical source for computers	There were inadequate electrical and network outlets for computers. Also, the ability to change computer locations was not possible.	6
I-10	Running out of space	There was no room for expansion when operations grew or were added.	6
I-4	Heating/cooling changeover adjustments	Room temperature set points were all the same throughout the building and were switched from summer to winter based upon a date, not weather.	5
I-7	Ballast problems (lighting 4' fluorescent)	There was significant light flicker that caused eye strain and headaches throughout the facility.	5
I-2	Hallway drafts	Air movement could be easily felt and sometimes heard in the hallways as they were a central path for the return air.	1
I-11	Humidity problems causing interior wall separations	High humidity in the space resulted in deterioration in the exterior wall systems. Need to avoid high humidity and facility degradation.	0
I-14	Canopy paint peeling - building exterior	The exterior of the building was not maintained to project the expected image of the owner.	0
I-16	Increased airflow makes some people feel uncomfortable	Some of the staff members are very sensitive to airflow velocity and changes in velocity.	0

Question 10: What Must Be Accomplished for a Successful Project?

Response #	Responses	Clarification	Score
J-2	Total project within budget	The total project budget, going from initial inception through one year of operation, needs to be projected and then maintained.	29
J-1	Owner/AE/Contractor/CxA pleased with process	The Commissioning Team members see value from the Commissioning Process and will utilize it on future projects.	18
J-3	Completion on or ahead of schedule	Schedule is achieved or exceeded, without compromise to the other OPR.	17
J-9	Achieves the OPR	All OPR are achieved.	14
J-4	Owner's acceptance of the facility	The owner accepts the facility with no outstanding issues.	10
J-12	Easy to maintain	The facility’s systems and assemblies are easy to access and maintain.	10
J-10	Easier to do my work	Individuals are more productive at their jobs as they are not distracted by operational issues.	8
J-8	Minimize occupant complaints	The number of occupant complaints decrease by 90% from the current facility.	7
J-11	Functional work area	The work areas are functional and have flexibility to meet the changing needs of the different activities to be accomplished.	7
J-17	Mission of maintenance staff done more productively (also 5)	The O&M staff is not putting out fires (responding to calls), but is proactively maintaining the facility to avoid the calls.	7
J-21	O&M staff well trained	Training of the O&M staff was successful and has been verified.	5
J-22	O&M staff receives great manuals and record drawings	The documentation for operating and maintaining the facility is systems based and provides the information in an easily accessible format.	5
J-23	Achieve LEED™/Energy Star™ certification	Achieve recognition of the facility's sustainability and energy efficiency.	5
J-16	No problems	There are no problems during the first year of occupancy.	3
J-18	Energy performance at or below expectations	Operate the facility to achieve all the OPR, including energy.	3
J-29	Low maintenance landscaping	The landscaping requires little maintenance and effort to keep it thriving.	3
J-32	Happy occupants	The occupants look forward to coming to the facility.	3
J-5	O&M staff not overburdened (see 17)		0
J-7	Accepted by the community	The surrounding community accepts the facility and takes pride in having it in their area.	3
J-13	Mechanical equipment easy to access	All equipment that requires periodic maintenance is easily accessible.	2
J-19	Minimal call backs	Contractors are not required to come back after building turnover to fix mistakes.	2
J-30	No requests for space modifications	During the first two years of operation, there are no requests to modify the space layout.	2
J-25	Cost savings identified greater than Commissioning Process cost	There is at least a 3 to 1 payback on the investment into the Commissioning Process.	1
J-34	No lawsuits	There are no issues that result in arbitration or a lawsuit.	1
J-6	Beautiful building that meets design requirements		0
J-14	Lower accident incident ratio (during occupancy)	Employee accidents that occur during operating hours decrease in number.	0
J-15	Comfort of building occupants	The comfort of the occupants is rated high.	0
J-20	Attract more new members	Use the facility to educate the industry and attract new members.	0
J-24	No contractors lose money	Contractors make more profit (including the design professionals).	0
J-26	Good PR	There are at least ten favorable articles written on the project in non-	0

Response #	Responses	Clarification	Score
		ASHRAE publications.	
J-27	Number of sick days decreases	The average number of sick days taken per employee is reduced by at least 15%.	0
J-28	Project adequately portrays status and image of the Society	Society's contributions to the world are recognized through the facility.	0
J-31	Approved test documents	Prior to occupancy, all test documents have been completed and accepted.	0
J-33	No major product failures	No major warranty callbacks due to defective products.	0
J-35	No grievances by employees	No grievances are filed by an employee due to the new facility.	0
J-36	No design failures	There are no non-owner initiated change orders and no need to utilize the design professional's errors and omissions insurance.	0
J-37	Is able to adapt to changes without investment (space flexibility)	The space can be easily modified by the O&M staff without the need for additional funds.	0

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

INFORMATIVE ANNEX K

BASIS OF DESIGN

This annex provides an example of how to implement part of Guideline 1-200X. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X, and other applicable commissioning technical guidelines tailored to their specific projects. An example is NIBS Guideline 3-2006, Exterior Envelope Technical Requirements for the Commissioning Process.

In addition to the general requirements of Annex K in Guideline 0, this annex addresses specific requirements for the HVAC Basis of Design document, and must be coordinated with the Basis of Design documents of other technical guidelines. The HVAC Basis of Design document records the major thought processes and assumptions behind the HVAC design decisions made to meet the Owner's Project Requirements as they relate to the HVAC system. The HVAC design professional must read the entire Owner's Project Requirements before starting the HVAC Basis of Design. The HVAC Basis of Design document captures important information linking the "what" of the Owner's Project Requirements and "how" of the HVAC system design.
The objective of specifically documenting HVAC Basis of Design information is to provide the parties involved in a project, at each phase in the process, an understanding of the underlying thinking that led to the selection of specific HVAC components, systems, and system integrations. This includes documenting the type of HVAC system chosen as well as documenting those rejected during the initial phase of the project and why they were selected or rejected. A design narrative that provides an overview of systems in verbal format is usually an integral element of the Basis of Design.
The specific contents of the HVAC Basis of Design document will vary from project to project and system to system, but in general should address:

1. List specific codes, standards, and guidelines considered during the design of the facility.

   - List the specific building codes being utilized for the design of the project. This should include the title of the code and the year (e.g. International Mechanical Code – 2000 edition).
     Example:
     The facility will be designed under the current Building Code for Atlanta, GA. This code is the International Building Code -2000 edition with Georgia amendments. The HVAC system will be designed to comply with the International Mechanical Code – 2000 edition and the Georgia amendments.

   - List specific standards (including year of publication) being utilized in the design of the project (e.g. ASHRAE 62-2000, NFPA 45-2000)
     Example

The HVAC system will be designed in accordance with the following additional standards in effect as of September 1, 2004. (Note: These do not apply at the time of issue of this Guideline (1-200X), but were current when this example OPR was developed. For current projects use the current versions of all references. This is merely an example.)

1. ASHRAE Standard 15-2001 “Safety Standard for Refrigeration Systems”
2. ASHRAE Standard 34–2001 “Designation and Safety Classification of Refrigerants”
3. ASHRAE Standard 52.1–1992 “Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter”
4. ASHRAE Standard 52.2–1999 “Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size”
5. ASHRAE Standard 55–1992 “Thermal Environmental Conditions for Human Occupancy”
6. ASHRAE Standard 58–1986 “Method of Testing for Rating Room Air Conditioner and Packaged Terminal Air Conditioner Heating Capacity”
7. ASHRAE Standard 62–2004 “Ventilation for Acceptable Indoor Air Quality”
8. ASHRAE Standard 90.1–2001 “Energy Standard for Buildings Except Low-Rise Residential Buildings”
9. ASHRAE Standard 90.1-2001 “User’s Manual” - for Guideline 90.1-2001
10. ASHRAE Standard 111-1998 “Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and refrigeration Systems”
11. ASHRAE Standard 114-1996 “Energy Management Control Systems Instrumentation”
12. ASHRAE Standard 129-1997 “Measuring Air Change Effectiveness”
13. ASHRAE Standard 154-2003 “Ventilation for Commercial Cooking Operations”

- List specific guidelines and year of publication being utilized in the design of the project (e.g. Guideline 1-200x).
  Example:
  The following Guidelines will be utilized during the design of the HVAC system.
  1. U.S. Green Building Design Guide
  2. ASHRAE Guideline 0–2005 “The Commissioning Process
  3. ASHRAE Guideline 1–200X “The HVAC Commissioning Process
  4. ASHRAE Guideline 4-1993 “Preparation of Operating and Maintenance Documentation for Building Systems”
  5. ASHRAE Guideline 5–1994 “ Commissioning Smoke Management Systems”
  6. ASHRAE Guideline 12-2000 “Minimizing the Risk of Legionellosis Associated with Building Water Systems”
  7. ASHRAE Guideline 13-2000 “Specifying Direct Digital Control Systems”
  8. ASHRAE Guideline 14-2002 “Measurement of Energy and Demand Savings”
  9. ASHRAE Guideline 16-2003 “Selecting Outdoor, Return and Relief Dampers for Air-Side Economizer Systems”

2. List information regarding ambient conditions used during the design.

- List the outdoor design conditions (e.g. temperature, humidity, wind speed, and quality of outdoor air), the source of that information (e.g. ASHRAE Handbook, Atlanta, GA, 99% design), justification for this level, and relationship to the OPR.
  Example

Geographic Information (2001 ASHRAE Fundamentals, Chapter 27)

Location: Atlanta, GA
Latitude: 33.65 º North Latitude
Longitude: 84.42 º West Longitude
Altitude: 1033 ft.

Climatic Conditions (2001 ASHRAE Fundamentals. Chapter 27)

Cooling:

Dry bulb:	91 ºF.	(1.0%)
Coincident Wet bulb:	74 °F.	(1.0%)
Wet bulb:	76 °F.	(1.0%)
Dry bulb:	93 °F.	(0.4%)
Coincident Wet bulb:	75 °F.	(0.4%)
Wet bulb:	77 °F.	(0.4%)
Mean Daily Range:	17 °F.	
Prevailing Wind	300 º	
Wind Speed	9 mph	
Extreme	96 °F.	

(Use 1.0% value for typical spaces, 0.4% value for critical temperature control spaces)

Dehumidification:

Dew-point:	73 °F. (1.0%)
Humidity Ratio:	128 grains per lb of dry air (1.0%)
Coincident Dry bulb:	81 °F. (1.0%)
Dew-point:	74 °F. (0.4%)
Humidity Ratio:	133 grains per lb of dry air (0.4%)
Coincident Dry bulb:	82 °F. (0.4%)

(Use 1.0% value for typical spaces, 0.4% value for critical temperature control spaces)

Winter:

Dry bulb:	23 °F.	(99 %)
Dry bulb:	18 °F.	(99.6%)
Prevailing Wind	320 º	
Wind Speed	12 mph	(99.6%)
Extreme:	9 °F.	

(Use 99% value for typical spaces, 99.6% value for critical temperature control spaces)

Based on using the above design temperatures, there will be approximately 2% of the time (175 hours per year) when the system cannot maintain normal operating parameters.

3. List assumptions regarding the usage of the facility.

- Describe the type of occupancy and usage of the facility and how it affects the HVAC system and its operation. This includes information on the types of spaces in the facility and the unique challenges they bring to the HVAC system (e.g. classrooms require large amounts of outside air that has to be heated, cooled, dehumidified, or humidified).
  Example:
  The facility being built is a new headquarters building for ASHRAE in Atlanta, GA. Typical occupancy is office use with typical auxiliary spaces. The building is expected to be approximately 60,000 gsf with 3 floors. Occupancy is 80 to 105 people. Special events will boost the visitor population from 25 to 150 people per day. The building occupancy schedule shall be as follows:

Occupancy Schedule

Day of Week	**State**	**Morning Warm-up**	**Occupied**	**Unoccupied**	**Special Events**
Monday to Friday	On	6:00 a.m.	7:00 a.m.	6:00 p.m.	6:00 p.m.
	Off	7:00 a.m.	6:00 p.m.	6:00 a.m.	10:00 p.m.
Saturday	On	N/A	9:00 a.m.	1:00 p.m.	7:00 a.m.
	Off	N/A	1:00 p.m.	Midnight	6:00 p.m.
Sunday	On	N/A	N/A	Yes	7 a.m. – 6 p.m.
Holidays	Off	N/A	N/A	Yes	N/A

Occupant/space use requirements and schedules – an occupant of ASHRAE Headquarters is defined as anyone who is in the space more than 3 hours. The conference rooms and influx of people during special events will require additional consideration for outside air requirements.

4. List expectations regarding system operation and maintenance:

- List in general how the system is suppose to operate.
  Example:
  The HVAC system is designed to operate with minimal interface from the occupants. The system will be provided with DDC controls which will control the operation of the system during normal operating conditions. Switchover from heating to cooling and occupied to unoccupied modes of operation will be automatic. The users will be provided with the ability to override the automatic controls for a limited amount of time.

- Discuss maintenance staffing available or required as it relates to different HVAC systems and the OPR.
  Example:

  The building owner will be utilizing ASHRAE's own personnel for operations and maintenance. The personnel have 10 to 25 years of experience and are proficient in basic maintenance techniques. Additional training will be provided for the selected systems and their intended operation. The systems will be reviewed with the operation and maintenance personnel to determine additional training requirements needed for the specified equipment and systems.

5. List performance criteria that the system was designed to meet and link them to the OPR.

- Describe any specific criteria the owner has for HVAC systems.
  Example:
  Key items from the Owner's Project Requirements concerning the HVAC system include the following:
  1. Indoor Air Quality – no odors, air shall smell fresh
  2. Uniform temperature in occupant zone (±2 ºF)
  3. Space Humidity control
  4. Energy Efficiency (15% better than ASHRAE Standard 90.1)
  5. Life Cycle cost decisions
  6. 25 year life of HVAC
  7. Individual Temperature Control
  8. Flexibility
  9. Equipment Designed for ease of Maintenance and non-disruptive to occupants
  10. Noise Restrictions at property line

  Warranty shall be 1 year for items less than $100,000 (assume parts only), 5 years for items greater than $100,000 and include parts, labor, and consumables.

- List specific owner performance criteria that affect the HVAC system. This can include energy usage, comfort levels, indoor air quality issues, level of individual control of the system, and maintenance issues.
  Example
  Specific Owner Directives for the HVAC system include the following:
  1. Use Manufacuter [X] for controls to conform with other facilities
  2. Use only a screw chiller for good part-load performance
  3. Do not use any duct liner
  4. Do not use fan powered terminal units
  5. Do not use CFC's or HCFC's

6. List specific design methods, techniques, software used in the design.

- List known and assumed factors, calculation methodology, and computer programs utilized in calculating the heating and cooling loads. This includes data on internal equipment loads, lighting loads, people loads, building envelope U-values, fenestration U-values and solar heat-gain coefficient.
  Example:

  Occupancy for cooling load calculations will be based on occupancy density information provided in ASHRAE Standard 62. For sizing central equipment, maximum building occupancy will be based on 80 staff and 150 special event visitor populations.

  Lighting loads will be based on the lighting layout. Equipment loading will be based on anticipated equipment with an allowance for an increase of 15%. Solar heat gain through windows and U-values of walls and

windows will be calculated using ASHRAE data and the selected wall, roof, and window systems selected by the Architect.
Heating and cooling loads will be calculated using XYZ computer program. A safety factor of 10% will be utilized at the room level. Adding the safety factor at this level will add a 10% safety factor to all the system. This program bases the heating and cooling loads on the Total Equivalent temperature Differential Method with Time Averaging as originally introduced in the 1967 ASHRAE Handbook of Fundamentals. The air ducts will be sized using the equal-friction method during design. Duct static pressure calculations will be calculated using XYZ computer program, which takes into account static regain in the duct system. The complete duct system will be modeled, not just the "longest run." The results of the program will be utilized to see if any sections of duct are contributing to a high static-pressure requirement. The piping system will be sized based on an office standard for velocity and pressure drop. The pump heads will be calculated using XYZ computer program, which is based on the Darcy-Weisbach methodology.

Energy analysis will be performed using the DOE2 program and the following criteria:

(i) Life of HVACR systems = 25 years
(ii) Return on investment = 7%
(iii) Inflation rate = 3%
(iv) Productivity rate = $1,600/hour
(v) Fuel escalation rate = 2%
(vi) Current energy rates
(vii) Maintenance cost estimates
(viii) Estimated construction cost

Energy conservation measures will be ranked by their return on investment. If budget constraints prevent all viable (return on investment greater than 7%) measures from being implemented, then the measures with the highest rate of return will be selected up to the budget limitations.

7. Provide a narrative description of the HVAC design.

- Provide a general description of the HVAC system selected for the project and explain why it was selected. Also discuss which types of systems were rejected.

Example:

HVAC Systems – General

The Owner through the OPR has requested a system that is energy efficient, easy to maintain, provides good indoor air quality, and is selected on a life-cycle cost basis, i.e., the owner wants a system based on life cycle cost, not just first cost. An energy model of the facility will be performed to analyze various options concerning the HVAC system.

In order to provide a system that is easy to maintain, central air handling system with chilled water and hot water coils was selected over distributed unitary type equipment. Water source heat pumps, fan coil units, and other small packaged heating and cooling systems require maintenance to be performed throughout the facility versus in central mechanical rooms. Central equipment will be located in a mechanical room versus on the rooftop to facilitate maintenance requirements. This makes maintenance easier and disturbs the occupants less.

The air system selected is a variable-air-volume system utilizing variable-volume induction terminal units. A central chilled water system will provide chilled water to the air handling units. A central hot water boiler system will provide hot water to the air handling units, and unit heaters.

- List indoor design conditions (e.g. temperature, humidity, space pressurization, noise criteria, and air quality) by space type, the source of that information (e.g. ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*), justification for these conditions, and how they address the Owner's Project Requirements.
  Example:

  Indoor Conditions

  Cooling:

  Offices: 76 °F., 50% max. RH

  Heating:

  Offices: 71 °F., 30% min. RH (Setback: 55 °F.)

  The above temperatures are based on ASHRAE Standard 55-1992 for an average clothing insulating value of 0.9 clo in the winter and 0.5 clo in the summer for people during light sedentary activity (≤1.2 met) with a dissatisfaction rate of 10%. This is in response to the OPR that requires comfortable working conditions for office workers in typical business dress. As workers will have different levels of clothing, their insulating values will vary and their satisfaction at these temperatures will vary. Greater levels of individual control will result in a greater satisfaction rate.

- List outdoor air requirements, calculation methodology (ventilation rate procedure or indoor air quality procedure), references used to determine air quantities (e.g. ASHRAE 62-2004), and how these air volumes address the Owner's Project Requirements.
  Example:

  The minimum outdoor air requirements will be based on ASHRAE 62-2004. The outdoor air will be based on the ventilation rate method. For high occupancy areas with great variability in occupancy, the outside air will be reset from the minimum rate for the area to the maximum determined by the ventilation rate procedure based on CO2 sensors in the space or return air from the space. With the VAV system, the minimum airflow to the space will be adjusted based on the percentage of outside air in the supply air determined by the ratio of the air flows measured by the airflow measurement stations in the outside air duct and supply duct.

- List the fuel sources available at the site, specify which fuel source was selected, and why that fuel was selected.

Example

The fuel sources available at the site include electricity, natural gas, propane, and oil. Natural gas was selected as the primary heating fuel with propane selected as a backup fuel. Natural gas was selected as a clean burning cost effective fuel for heating the facility. Propane was selected as a backup fuel to take advantage of an interruptible natural gas rate. Propane was selected over oil as a clean-burning, cost-effective fuel.

- Discuss hydronic (hot water, chilled water, or condenser water) systems, steam/condensate systems, refrigerant piping systems, and water treatment systems considered for the facility. The discussion should include which systems were selected, why they were selected, and why other systems were not selected. The discussion should include the types of pumps to be utilized in the systems, any special considerations, along with control methodology (e.g., 2-way control valves, 3- way control valves, variable-speed drives, or differential bypass). The methodology utilized to size the pipe system (e.g. office standard based on pressure drop and/or maximum velocity) along with the how the pump heads will be calculated (e.g. computer program by XYZ company utilizing Darcy-Weisbach or Hazen-Williams methodology).
Example

The chilled water system will include multiple chillers with a variable volume primary system. The chilled water coils will be served by two way control valves. A bypass line will be provided to allow the minimum flow in the chiller barrel to be maintained during periods of low demand. The system will be designed on a 14 °F ΔT. The system will consist of two chilled water pumps with variable speed pumping. One pump will be standby. Piping will be black steel. The contractor will be allowed to utilize copper pipe for sizes less than 2” in diameter with dielectric fittings between the dissimilar metals. All chilled water piping will be insulated.
The hot water system will consist of multiple boilers. The heating system will be based on 140 °F to 180 °F hot water. The distribution system will be primary-secondary loop variable flow system with two-way control valves on the hot water coils. Each boiler will have an individual circulating pump to maintain the minimum flow rates required for a water tube boiler. The system will consist of two hot water pumps with variable speed pumping. One pump will be standby. Piping will be black steel. The contractor will be allowed to utilize copper pipe for sizes less than 2” in diameter with dielectric fittings between the dissimilar metals. All hot water piping will be insulated.

If a water-cooled chiller is provided, a condenser water system will be provided. The condenser water system will consist of the cooling tower, the piping system, the condenser water pumps, and the chiller condenser barrels.
The closed loop water systems (hot and chilled water system) will be thoroughly cleaned and flushed upon completion of the systems. The final system fill will be neutralized and then treated with corrosion inhibitors and oxygen scavengers. A pot feeder will be provided for each system for the addition of chemicals.

If a cooling tower is utilized, an automatic water treatment system will be provided. The system will reduce concentrations of solids through a regulated bleed valve based on a conductivity controller. Automatic feed pumps will control alkalinity, scale, and biocide levels.

- Discuss the air distribution system planned for the facility. This should include whether there is a duct system, the type of system (e.g., constant volume or variable volume, dual duct, and/or multi-zone), the type of duct to be utilized (e.g. factory fabricated round/flat oval, rectangular, single wall, double wall, internal lining, external insulation, and/or anti-microbial coatings) air flow control strategies (e.g. manual balancing dampers, variable air volume terminal units, and/or variable air volume diffusers), the type of variable air volume terminal unit (e.g. vav single duct terminal unit, vav fan powered series unit, vav fan powered parallel unit, vav induction unit, vav or cav dual duct terminal unit, and/or bypass air unit), types of fans utilized (e.g. forward curved, backward curved, airfoil, utility sets, inline, cabinet, vane axial, dome fans, upblast roof fans, mixed flow high dilution laboratory exhaust fans, and/or plug or plenum fans), the types of diffusers (e.g., laminar flow, louvered face, linear, perforated face, and/or high diffusion), grilles and registers utilized, filtration levels considered (e.g., MERV rating, two-inch throwaway, rigid cartridge, bag, HEPA, bag-in/bag-out, charcoal, and/or roll filter), and kitchen hoods. The methodology for sizing the duct system (e.g. equal friction, static regain, T-method Optimization, or constant velocity) along with the methodology of calculating the pressure loss in the duct system (equivalent lengths, fitting loss coefficients, static regain) should be discussed, including any computer program utilized.
  Example

  The OPR requires a system that has good air distribution yet conserves energy. Typically the best air distribution systems are constant volume for maintaining diffuser throws and room circulation. Series fan powered terminal units have been used for years to allow varying the primary air while maintaining constant room airflow. The fan powered terminal units require regular maintenance for filter changeout and motor changeouts before the end of a 25-year life. The small fans and motors are inefficient compared to the central air-handling units. A typical variable air volume terminal unit will allow the airflow to be reduced from design flow to about 40%. This will affect the performance of the diffusers. The variable volume induction terminal unit allows the primary airflow to be varied down to 40% of design while inducing plenum air (or ducted room air) into the unit such that total airflow will be approximately 80% of the design flow. This has a minimal effect on the diffusers. The variable volume induction terminal units require a higher static pressure to operate than fan powered units, but the overall energy consumption is less since the additional static pressure is handled by a more efficient fan and motor. The terminal units will be lined with a rigid fiberglass board with a reinforce foil face.

  The air handling units for this project consist of a double wall unit with return fan, relief damper section, outside air intake section (with minimum and maximum outside air damper), ASHRAE MIRV 13 rigid filters with a

MIRV 7 pre-filter, hot water coil, chilled water coil, supply fan, and total energy recovery wheel with exhaust fan (depending on results of energy analysis). Access doors will be a minimum of 18-inches wide and extend the full height of the unit and will be provided with full height stainless-steel piano hinges. Access doors will be provided at each fan inlet section and filter section, on both sides of the heating and cooling coil, and on both sides of the heat recovery wheel. The unit will be a draw-thru arrangement to allow the fan heat to provide a small amount of reheat so the supply air is not saturated. The chilled-water drain pan will be double sloped, insulated and constructed from stainless steel. The drain pan will be properly trapped. The base of the unit and the housekeeping pad will be of sufficient height to allow proper trapping of the drain pan. The supply and return fan will be plenum fans with variable frequency drives.

The duct system will be single wall spiral round of flat oval from the air-handling unit to the terminal units. Spiral round and flat oval duct is more efficient at transporting air than rectangular duct. The edge velocities are higher and dead corners are eliminated. This helps keep dust and dirt from settling at the corners and creating a food source for mold. Leakage rates for spiral duct is lower than rectangular duct per SMACNA Guidelines. All ductwork will be concealed. The duct system from the terminal unit to the diffusers shall be rectangular low-pressure duct and shall be designed for a maximum pressure drop 0.15" w.g. The duct will have at least one elbow between the terminal unit and the drop to the diffuser. Flexible duct shall be limited to a maximum of 3' for the connection between the duct and the diffuser. The return duct will be rectangular duct extending to near the center of each area of the building. A return air plenum will be utilized for the return system.

The toilets and janitor closets will be exhausted through a common exhaust system through a total (sensible and latent) energy recovery coil or run-around-coil (sensible only) if the energy analysis shows that either is economically feasible.

- Discuss the central HVAC equipment to be utilized on the project. This includes air handlers, heat recovery units, and exhaust fans that are typically located in a mechanical room or on the roof and that serve multiple areas. This would include the type of units (e.g. components included, modular air handling unit, custom air handling unit, energy recovery unit, heat pumps, and/or packaged rooftop units).
  Example
    The chilled water system will consist of two screw chillers to provide chilled water to the air-handling units. The sizing of the chillers will be based on peak and part load requirements. The chillers may each be sized for 50% of the peak cooling load or a 25% - 75% split or some other fraction depending on the outcome of an energy and life-cycle analysis for the facility. The chillers will be either air-cooled or water-cooled, depending on an economic analysis of energy usage, water usage, and maintenance requirements. There are some constraints on the municipal water system in the area that would favor the use of an air-cooled chillers.

Chillers will be bid-based peak -capacity and part-load performance. Factory testing witnessed by the Engineer and Owner will be required for peak performance as well as 4 part-load points. The chilled water distribution system will be a variable primary flow system with two-way control valves on the chilled water coils. A bypass line with control valve will be provided at the chiller to maintain the minimum required flow rate for the chiller.

Centrifugal chillers were rejected because the owner requested screw chillers based on the part load performance of the chiller.

The hot water system will consist of multiple modular boilers. The boilers will be copper fin-tube boilers with modulating control. Boilers will be dual fuel (natural gas and propane) to allow the owner to take advantage of interruptible natural gas rates. The boilers will be 85% efficient, non-condensing boilers. While condensing boilers will have efficiencies up to 98%, that is based on 60 °F entering water temperature. The heating system will be based on 140 °F to 180 °F hot water. Special attention will be paid to water flows and volume in the boiler primary loop to avoid over-cycling the boiler. The boiler loop pumps will operate for five minutes after the boiler shuts down to remove the heat from the boiler tubes to prevent the water from boiling in the boiler.

- Discuss the decentralized HVAC equipment to be utilized on the project. This includes water source heat pumps, fan coil units, unit heaters, radiant heaters, single zone package unitary equipment, direct-fired make-up air heaters, and other equipment that is distributed throughout the building and typically serves single zones.
  Example

  The mechanical rooms will be heated with hot-water unit heaters. The entry way will include cabinet unit heaters to reduce drafts. Warehouse space requiring heating only will be provided with direct-fired natural gas heaters. The heater will be based on a 160 °F rise. While most direct-fired heaters are based on a 140 °F rise, a unit with a higher heat rise requires less outside air to provide the same amount of heat to the space since the heat must first be heated up to room temperature to be effective. The high temperature rise direct-fired heaters have been found to use less energy than infrared heaters and unit heaters, while maintaining a more uniform space temperature.

  A decentralized heating and cooling system for the entire facility such as fan coil units or water source heat pumps was dismissed because maintenance of the system would cause disruption to occupants for changing filters and other routine maintenance if the equipment was distributed throughout the facility.

- Discuss the type of control system and the level of instrumentation selected for the facility. The system should be described according to the basis of the control system (pneumatic, electric, DDC, and/or factory unit mounted controls). In addition the level of monitoring, trending, and integration required to meet the Owner's Project Requirements should be discussed. This would include any special requirements the owner has concerning control systems, such as pneumatic, electric, DDC, integration with other systems

Example:

> The facility will be provided with a DDC system by manufacturer [X]. The system will be a distributed control system. All control valves and damper actuators will be electric, i.e., there will be no pneumatics on the project. The DDC system will monitor energy usage by system and provide trend logging of system performance. The DDC system will be accessible through the intranet and will allow users to view the performance of the system and adjust the temperature setpoint for their individual area.

8. Provide a narrative of the operation of the system.

- Describe the intended operation of the system to include hours of operation, general sequence of operation (heating, cooling, dehumidification, occupied, unoccupied, and emergency) and how it meets the Owner's Project Requirements. Some areas may require 24-hour operation where others may be during normal business hours. The HVAC Basis of Design should address these differing requirements as well as extended-hour operation. Example:

> The HVAC system is intended to operate during the occupied hours and special event hours as shown in the occupancy schedule. During normal operating hours, the fan systems will operate continuously to provide proper ventilation and temperature control throughout the facility. During unoccupied hours, the fan system will be cycled to maintain a setback condition.
>
> The control system will be a DDC control system as manufactured by [X] control manufacturer. The existing facilities utilize this system and the maintenance and operation personnel have been trained on the system.
>
> Outside air will be measured directly and controlled by a minimum outside air damper. The damper will be adjusted by a five-minute average of the outside air readings to reduce the effects of transient wind readings. Outside air will be controlled to maintain the minimum required by ASHRAE Standard 62 or for proper building pressurization. The outside air damper will be modulated to maintain the outdoor air flow at its setpoint. If the damper is fully open and the outside air is below its set point, the return fan control will be overridden and the fan slowed down to reduce the return air and increase the outside air flow provided that the air balance calculations show the make-up air for exhaust and building pressurization is greater than the minimum outside air requirements. If minimum outside air requirements for IAQ are the driving factor for determining the outside air, then the return air damper will be modulated closed if the minimum outside air damper is fully open. A continuous amount of relief will be provided.

The supply fan airflow will be controlled with a variable frequency drive to maintain static pressure in the duct at approximately two thirds of the path downstream from the fan. The setpoint for the static pressure sensor will be reset based on maintaining at least one terminal unit at 95% open. The return fan airflow will be controlled with a variable frequency drive to maintain a set differential air flow from the supply fan. This differential will be based on the supply air minus the exhaust air and an amount to allow for building pressurization. Supply and return airflow will be measured in the ducts versus at the fan inlets. While fan inlet air flow measurement is popular, the airflow patterns in the fan inlet are not conducive to accurate measurement. While building pressure has been used in the past to control return fans, obtaining accurate pressure readings is difficult. The wind blowing on the side or along the edge of building can change the pressure at the building wall such that overall building pressure maybe negative or positive, causing problems with opening or closing doors.

The units will be designed to provide a constant discharge temperature. The hot and chilled water coil will be provided with two-way modulating control valves. The units will be provided with enthalpy economizer cycles to provide free cooling.

The chilled water system will be a controlled to provide a constant chilled water temperature. The variable frequency drive on the pump will be controlled to maintain a constant differential pressure across the supply and return at the furthest air handling unit. The flow through the chiller will be measured, and when the flow falls below the minimum required by the chiller, a bypass valve in the chiller room will be modulated open as necessary to maintain the minimum required flow. Selection of the chillers to be operated will be based on the cooling demand and energy profiles of the chillers in order to minimize energy usage.

9. Provide a list of the major pieces of equipment and the specific manufacturers utilized as the basis of design.

Example: The HVAC system design was based on the following equipment. Additional manufacturer's considered equal in performance are also listed. Additional manufacturer's that can meet the performance specifications will be considered.

Equipment	**Basis of Design**	**Additional Manufactures**
Chillers	XYZ	C, D, M, T, or Y
Air Handling Units	XYZ	C, D, M, T, or Y
Fans	ZYX	A, C, G, or P
Cooling Towers	TYZ	B, M, or T
Pumps	ZYX	A, B, or T
Boilers	YZX	A, P, or T
DDC	X	No substitutes
Airflow Measurement	E	No substitutes
VFD	G	A, T, or Z

Terminal Boxes	T	A, P, Tb, or Ti
Grilles, Registers, Diffusers	T	A, P, Tb, or Ti
Make-up air Units	C	G, T, or F

10. Update the Basis of Design

- As decisions concerning the HVAC system are finalized and calculations are completed, the Basis of Design should be updated.
  Example:
  The following changes were made to the Basis of Design as the design progressed. They have been incorporated into the above narrative.
  List changes and why.
  Attached is a copy of the revised calculations for the following:
  Energy Analysis
  Heating and Cooling Loads
  Fan static pressure calculations
  Pump Heads
  Outside air calculations
  Air Balance

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

INFORMATIVE ANNEX L
SPECIFICATIONS

This annex provides an example of how to implement part of Guideline 1-200X. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005 "The Commissioning Process", Guideline 1-200X, and other applicable commissioning technical guidelines tailored to their specific projects. An example of a related guideline is NIBS Guideline 3-2006, Exterior Envelope Technical Requirements for the Commissioning Process.

PART 1 - ORGANIZATION OF COMMISSIONING SPECIFICATIONS

- Commissioning specifications include only the construction-phase commissioning tasks, which are only a portion of the overall commissioning process. Specifications (as part of the construction contract documents) should include only the requirements that obligate the contractor(s) for performance of services during the life of the construction contract plus the correction period and other special warranty periods. Tasks and activities identified for performance during the predesign and design phases, and those to be completed after the owner's acceptance, cannot be made an obligation of the contractor, which is the sole objective of the construction contract documents in general, and specifications in particular. Therefore, the owner should contract separately with the commissioning authority (CxA) to perform commissioning services.

- General Commissioning Requirements:

  Specifications in Division 01 include the general requirements, for the Contractor, relating to commissioning activities. Specific guidance on Division 01 is included in Guideline 0-2005, The Commissioning Process. Division 01 Section "Multiple Contract Summary" describes how separate contractors in a multiple-prime arrangement should interact with the CxA and describes the role of the separate contractors as that role relates to commissioning. Specify administrative procedures for commissioning in Division 01 Section "General Commissioning Requirements." The remainder of the Specification Sections, with the exception of Division 01 Section "Temporary Facilities and Controls," should be mute on the subject of who performs certain parts of the Work. Other Sections should describe the specific commissioning requirements for systems interface and functional integration. Systems and equipment Sections should identify only field quality-control testing requirements and should identify the subject system, assemblies, equipment, or components that will be commissioned as part of an identified parent system with a reference to the appropriate commissioning Sections.

- HVAC Commissioning Requirements:

Division 23 Section "Commissioning of HVAC" includes specific commissioning requirements for HVAC systems, assemblies, equipment, and components to supplement Division 01 Section "General Commissioning Requirements." These two Sections must be read together to understand the full scope of the HVAC&R commissioning process. Division 23 Section "Commissioning of HVAC" includes commissioning activities from the simplest to the most complex systems. The range of activities includes tasks required for individual items of equipment; tasks required for subsystems and systems; and finally, tasks required for system integration. The testing of individual items of equipment that is part of commissioning relates to the equipment's performance within the system in which it functions. Otherwise, equipment testing is actually part of field or source quality control. The testing specified in the commissioning of a subsystem (e.g., an air-distribution system) or a system (e.g., an HVAC system) verifies the performance of the subsystem's or system's components' ability to collectively perform according to the OPR and the BoD. Finally, the testing of system integration verifies that the various integrated systems (e.g., life-safety systems including fire alarms, emergency generators, elevators, air-distribution systems, and paths of egress) all work together. For example, when a fire-alarm signal is generated from a device in the alarm system, elevators must return to the proper locations, automatic fire and smoke dampers should close, some fan systems should stop and some should start, smoke and fire doors should close, and much more. Then if power is interrupted, the emergency generator must start and assume the correct loads. Each system and its components can be tested individually, but tests for system integration are the real validation of the overall facility's ability to fulfill the OPR.

- Field Quality Control versus Commissioning:

  There is a difference between field quality-control testing and commissioning testing. The objective of field quality-control testing is to verify workmanship quality as prescribed by the Contract Documents; however, the Contract Documents usually do not include the kinds of performance requirements for systems that are included in the OPR and the BoD. When specifying field quality-control requirements, include procedures to verify that products are properly installed. An example is pressure testing of piping. Field quality-control test parameters are generally easy to define and the verification of results is easily documented. More importantly, an objective (as in the case of pressure testing of piping) is to determine whether or not the Contractor (Installer) made leak-free joints (a requirement stipulated in the Contract Documents). In contrast, commissioning includes testing to verify that a system is functioning according to the OPR and the BoD. Parameters for commissioning tests are more difficult to define because the writer of the parameters must know the OPR and the BoD and, therefore, the expected performance. Test results are more difficult to document; the objective is to verify that the OPR and the BoD are fulfilled. The OPR and the BoD are usually not included as "contract requirements" in the Contract Documents.

PART 2 - COMMISSIONING-RELATED ACTIVITIES

- Commissioning-related activities specified elsewhere include systems and equipment startup; testing, adjusting, and balancing; demonstration to and training of the Owner's operation and maintenance personnel; development and transmittal of operation and maintenance data; and field quality-control testing. The CxA should be involved in each of these activities when commissioning is part of the Project. However, requirements for these activities can and should be specified whether or not commissioning is part of the Project. If special requirements are necessary, they should be specified in the Section in which the system, subsystem, or equipment is specified. The following are examples:

- Startup: Include requirements in individual Specification Sections. For some equipment, require a factory-authorized service representative to perform the service.

- Testing, Adjusting, and Balancing: A separate Division 23 Section is devoted to this subject for HVAC&R installations, including central-station equipment, distribution systems, and terminal equipment and devices.

- Demonstration and Training: Include special requirements unique to the system or equipment in that system's or equipment's Section. Such unique requirements may relate to the scope and type of the training. Specify general requirements in Division 01 Section "Demonstration and Training."

- Operation and Maintenance Data: In individual Specification Sections, specify the unique requirements for the type of information required (e.g., particular requirements about parts lists, service schedules, preventive maintenance lists, and emergency operations). These subjects are specified broadly in Division 01 Section "Operation and Maintenance Data," which also specifies such general requirements as the arrangement of contents, number of copies, distribution and approval requirements, and similar requirements that apply without regard to specific systems or equipment

- Field Quality Control: In individual Specification Sections, the content of this article should include site tests, inspections, and manufacturers' field services relating to tests and inspections. These tests and inspections are intended to verify compliance with the Contract Documents and to verify the quality of the Contractor's workmanship. These tests are required whether or not commissioning is part of the Project. Commissioning tests, therefore, go beyond the requirements usually specified in this article.

- Adjusting: CSI's *SectionFormat* explains that the intent of the "Adjusting" Article is to include descriptions of final actions required to prepare installed products to perform properly. This title and explanation get to the root of the commissioning concept, but the term *adjusting*, as used here, is interpreted loosely to mean something less than commissioning.

PART 3 - COMMISSIONING TEST PROCEDURES

- The need for competitive bidding makes it difficult to write testing procedures during the contract document phase of project delivery. Specifications are written to achieve competition among contract bidders, material suppliers, subcontract bidders, and product and equipment manufacturers. For this reason, development of system and subsystem final test procedures is not achieved until actual equipment is selected and purchased by the Contractor(s) and subcontractors. The specifications should require development of commissioning test procedures by the

CxA with the cooperation of the Contractor(s). Review and approval of commissioning test procedures should be specified in a separate agreement between the Owner and the CxA and should be recognized and accommodated in the agreement between the Owner and the Architect (and other design professionals).

- HVAC&R systems descriptions are included in the BoD to document and communicate, to the Owner, the designer's solution for achieving the OPR. These systems descriptions must be updated as the design progresses and, along with the actual equipment included in the contract, should be used as a basis for developing construction checklists and testing procedures.

- Test procedures must be created by the CxA at a time when actual contract requirements are set (execution of the agreement between the Owner and the Contractor for construction) and when the Contractor has set subcontract and supplier agreements so the actual equipment to be provided on the Project is known. Many options are provided, to bidders, among all the equipment specifications; the final selection of the equipment will affect the development of construction checklists and test procedures. The CxA should be able to develop preliminary checklists and test procedures as system design progresses during the design development and contract document phases of project delivery. The CxA can make final adjustments to preliminary checklists and test procedures after execution of the construction contract.

PART 4 - TESTING ALLOWANCES

- Because actual checklists and test procedures cannot be determined until after execution of the construction contract, it is not practical to expect contract bidders to be able to anticipate manpower and testing equipment requirements to include in bids. One practical solution to this situation is to provide a commissioning testing allowance. This allowance can be in the form of a lump sum to be included in the bid (not recommended) or it can be in the form of a number of man-hours by specific technicians (recommended). In the latter, the contract bidders are in competition for the hourly rates for the technicians. If the CxA anticipates, because of the types of systems to be tested, the need for special testing equipment, then that can be included in the allowance or stipulated in the commissioning specifications. The amount of the allowance (whether in terms of costs or man-hours) should be included in Division 01 Section "Allowances." Division 23 Section "Commissioning of HVAC" should include an article stating only that the commissioning testing will be paid for by allowance and referencing the "Allowances" Section. This article should be accompanied by an article for unit prices describing how the allowance for testing can be adjusted to the actual amount or man-hour quantities. See the "Unit Prices for Adjusting Testing Allowances" Article for more information.

- The following is an example of text that could be added to Division 01 Section "Allowances":

    3.1 SCHEDULE OF ALLOWANCES

A. Allowance No. <**Insert number**>: Include a lump sum amount in the Contract Sum to pay for the quantities of man-hours listed below for providing technicians for the performance of commissioning testing at the direction of the CxA as specified in Division 23 Section "Commissioning of HVAC." Include hourly costs for required instrumentation, tools, and equipment for the performance of commissioning testing.

1. HVAC Systems Technician: <**Insert number**> man-hours.
2. HVAC Instrumentation and Control Systems Technician: <**Insert number**> man-hours.
3. Electrician: <**Insert number**> man-hours.

PART 5 - UNIT PRICES FOR ADJUSTING TESTING ALLOWANCES

- Allowances are a "best guess" for what might be required. There needs to be a way to make the actual contract sum reflect the actual work required. This is done for other activities, such as rock excavation, by adjusting the allowance according to an agreed price for a unit of Work. A unit price is an item to be included in a contractor's bid form as an agreed price for a stipulated unit of Work to be used to make final adjustments to the allowance. Division 01 Section "Unit Prices" describes a "unit of Work" for which the Contractor provides a price. This is done by providing space in the bid form for the technician's hourly rates. Then, if the actual number of man-hours exceeds the number stipulated in the allowance, it can be equitably adjusted at the conclusion of the commissioning testing. It is more difficult to define a "unit of Work" for adjusting a lump sum allowance because it is not possible to know how much technician time will be represented in each bid.

- The following is an example of text that could be added to Division 01 Section "Unit Prices":

3.1 LIST OF UNIT PRICES

A. Unit Price No. <**Insert number**> - Commissioning Testing Man-Hour Prices:

1. Description: An hourly amount for adjusting the commissioning testing man-hour quantity allowances for providing technicians to perform commissioning testing according to Division 23 Section "Commissioning of HVAC."
2. Unit of Measurement: Time in hours.
3. Hourly Amounts:

   a. HVAC Systems Technician: <**Insert number**> man-hours.
   b. HVAC Instrumentation and Control Systems Technician: <**Insert number**> man-hours.
   c. Electrician: <**Insert number**> man-hours.

PART 6 - CONSTRUCTION CHECKLISTS

- The following definitions are taken from ASHRAE Guideline 0-2005, *The Commissioning Process*.

- Checklists: Verification checklists that are developed and used during all phases of the commissioning process to verify that the Owner's Project Requirements are being achieved. This includes checklists for general verification, plus testing, training, and other specific requirements.

- Construction Checklist: A form used by the contractor to verify that appropriate components are on-site, ready for installation, correctly installed, and functional. Also see Checklists.

- Construction checklists consist of two types:

  - Component/Equipment Based: These construction checklists are utilized for components and pieces of equipment that are delivered, installed, and started during construction. There should be an individual checklist for each individual component or piece of equipment.

  - System/Assembly Based: These construction checklists are utilized for systems and assemblies where separate checklists cannot be applied to sub-components of the system or assembly. There should be a single checklist for the entire system.

- Construction checklists, like commissioning test procedures, are created by the CxA. Preliminary construction checklists can be developed as the design progresses and final construction checklists created after the construction contract is awarded and actual systems and equipment are known. The requirement for the CxA to develop these checklists should be included in the documents that form the agreement between the Owner and the CxA; the requirements for the Contractor to use them should be included in Division 23 Section "Commissioning of HVAC."

PART 7. INTRODUCTION TO GUIDE SPECIFICATIONS

This Specifications Section was written in cooperations with Architectural Computer Services, Inc. (ARCOM), who are the exclusive publishers and distributors of MASTERSPEC, a product of the American Institute of Architects. MASTERSPEC Section 23 0800 – Commissioning of HVAC is included in Guideline 1-200X by special agreement between ASHRAE, NIBS, and ARCOM.

7.1 Section 23 0800, included below has boxed notes that are instructions to the guide specifiers during editing of the specifications

7.2 The section includes optional text in boldface font and square brackets (e.g. **[optional text]**). These optional text items include text that often occurs and provides an easy way to include these requirements in the guide master for consideration for each project.

7.3 The section includes insert instruction in boldface font and angle brackets (<**Insert instructions**>). These instructions are placed where text must be inserted and provide some guidance about the nature of the text that must be inserted. Insert instructions are used when there are an infinite number of options that could occur, making the use of [**Optional text**] impractical.

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SECTION 230800 - COMMISSIONING OF HVAC

Revise this Section by deleting and inserting text to meet Project-specific requirements.
This Section must be edited with Division 01 Section "General Commissioning Requirements."
Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 7 - GENERAL

- RELATED DOCUMENTS

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

Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

- SUMMARY

Section includes commissioning process requirements for HVAC&R systems, assemblies, and equipment.

Related Sections:

Retain Section in subparagraph below because it contains the general commissioning process requirements that apply to commissioning of HVAC&R systems.

  - Division 01 Section "General Commissioning Requirements" for general commissioning process requirements.

- ALLOWANCES

Retain this article if commissioning testing is paid for by Contractor under an allowance. Do not include amounts.

Labor, instrumentation, tools, and equipment costs for technicians for the performance of commissioning testing are covered by the "Schedule of Allowances" Article in Division 01 Section "Allowances."

- UNIT PRICES

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

Commissioning testing allowance may be adjusted up or down by the in Division 01 Section "Unit Prices" when actual man-hours are computed at the end of commissioning testing.

- CONTRACTOR'S RESPONSIBILITIES

Perform commissioning tests.

Attend construction phase controls coordination meeting.

Attend testing, adjusting, and balancing review and coordination meeting.

Participate in HVAC&R systems, assemblies, equipment, and component maintenance orientation and inspection.

Provide information requested by the CxA for final commissioning documentation.

Provide measuring instruments and logging devices to record test data, and provide data acquisition equipment to record data for the complete range of testing for the required test period.

- CxA'S RESPONSIBILITIES

Include CxA responsibilities in this article that have an impact on Contractor's activities and responsibilities.

Provide Project-specific construction checklists and commissioning process test procedures for actual HVAC&R systems, assemblies, equipment, and components to be furnished and installed as part of the construction contract.

Verify and participate in commissioning testing.

Verify testing, adjusting, and balancing of Work are complete.

Verify test data, inspection reports, and certificates are included in Systems Manual.

- COMMISSIONING DOCUMENTATION

Provide the following information to the CxA for inclusion in the commissioning plan:

  - Plan for delivery and review of submittals, systems manuals, and other documents and reports.
  - Identification of installed systems, assemblies, equipment, and components including design changes that occurred during the construction phase.
  - Process and schedule for completing construction checklists and manufacturer's prestart and startup checklists for HVAC&R systems, assemblies, equipment, and components to be verified and tested.
  - Certificate of completion certifying that installation, startup checks, and startup procedures have been completed.
  - Certificate of readiness certifying that HVAC&R systems, subsystems, equipment, and associated controls are ready for testing.
  - Test and inspection reports and certificates.
  - Corrective action documents.
  - Documented verification of testing, adjusting, and balancing reports.

- SUBMITTALS

Paragraphs below are "Informational Submittals." See Division 01 Section "Submittal Procedures" for definition of "Informational Submittals."

Certificates of readiness.

Certificates of completion of installation, prestart, and startup activities.

PART 8 - PRODUCTS (Not Used)

PART 9 - EXECUTION

- TESTING PREPARATION

Certify that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.

Certify that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.

Certify that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.

Set systems, subsystems, and equipment into operating mode to be tested (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

Inspect and verify the position of each device and interlock identified on checklists.

Check safety cutouts, alarms, and interlocks with life-safety systems during each mode of operation.

Testing Instrumentation: Install measuring instruments and logging devices to record test data.

- TESTING AND BALANCING VERIFICATION

Prior to performance of testing and balancing Work, provide copies of TAB procedures, reports, sample forms, checklists, and certificates to the CxA.

Notify the CxA at least [**10**] <**Insert number**> days in advance of testing and balancing Work, and provide access for the CxA to witness testing and balancing Work.

Provide technicians, instrumentation, and tools to verify testing and balancing of HVAC&R systems.

- The CxA will notify testing and balancing [**Contractor**] [**Subcontractor**] [**10**] <**Insert number**> days in advance of the date of field verification. Notice will not include data points to be verified.
- The testing and balancing [**Contractor**] [**Subcontractor**] shall use the same instruments (by model and serial number) that were used when original data were collected.
- Failure of an item includes, other than for sound measurements, a deviation of more than 10 percent. Failure of more than 10 percent of selected items shall result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a deviation of 3 dB shall result in rejection of final testing. Variations in background noise must be considered.

- Remedy the deficiency and notify the CxA so verification of failed portions can be performed.

- GENERAL TESTING REQUIREMENTS

Scope of HVAC&R testing includes [**entire HVAC&R installation, from central equipment for heat generation and refrigeration through distribution systems to each conditioned space. Testing shall include measuring capacities and effectiveness of operational and control functions**] <**Insert scope**>.

Test all operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.

The CxA along with the HVAC&R [**Contractor**] [**Subcontractor**], testing and balancing [**Contractor**] [**Subcontractor**], and HVAC&R Instrumentation and Control [**Contractor**] [**Subcontractor**] shall prepare detailed testing plans, procedures, and checklists for HVAC&R systems, subsystems, and equipment.

Tests will be performed using design conditions whenever possible.

Simulated conditions may need to be imposed using an artificial load when it is not practical to test under design conditions. Calibrate testing instruments before simulating conditions. Provide equipment to simulate loads. Set simulated conditions and document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions.

Alter set points when simulating conditions is not practical.

Alter sensor values with a signal generator when design or simulating conditions and altering set points are not practical.

If tests cannot be completed because of a deficiency outside the scope of the HVAC&R system, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests.

If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.

- HVAC&R SYSTEMS, SUBSYSTEMS, AND EQUIPMENT TESTING PROCEDURES

Boiler Testing and Acceptance Procedures: Testing requirements are specified in Division 23 boiler Sections. Provide submittals, test data, inspector record, and boiler certification to the CxA.

HVAC&R Instrumentation and Control System Testing: Field testing plans and testing requirements are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

Pipe system cleaning, flushing, hydrostatic tests, and chemical treatment requirements are specified in Division 23 piping Sections. HVAC&R [**Contractor**] [**Subcontractor**] shall prepare a pipe system cleaning, flushing, and hydrostatic testing plan. Provide cleaning, flushing, testing, and treating plan and final reports to the CxA. Plan shall include the following:

- Sequence of testing and testing procedures for each section of pipe to be tested, identified by pipe zone or sector identification marker. Markers shall be keyed to Drawings for each pipe sector, showing the physical location of each designated pipe test section. Drawings keyed to pipe zones or sectors shall be formatted to allow each section of piping to be physically located and identified when referred to in pipe system cleaning, flushing, hydrostatic testing, and chemical treatment plan.
- Description of equipment for flushing operations.
- Minimum flushing water velocity.
- Tracking checklist for managing and ensuring that all pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

Energy Supply System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of [**oil**] [**gas**] [**coal**] [**steam**] [**hot-water**] [**and**] [**solar**] systems and equipment. Determine the sequence of testing and testing procedures for each equipment item and pipe section to be tested.

Refrigeration System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of chillers, cooling towers, refrigerant compressors and condensers, heat pumps, and other refrigeration systems. Determine the sequence of testing and testing procedures for each equipment item and pipe section to be tested.

HVAC&R Distribution System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of air, steam, and hydronic distribution systems; special exhaust; and other distribution systems, including HVAC&R terminal equipment and unitary equipment.

Vibration and Sound Tests: Provide technicians, instrumentation, tools, and equipment to test performance of vibration isolation and seismic controls.

<**Insert HVAC systems**>.

- PROCEDURES FOR SPACE PRESSURIZATION MEASUREMENTS AND ADJUSTMENTS

Before testing for space pressurization, observe the space to verify the integrity of the space boundaries. Verify that windows and doors are closed and applicable safing, gaskets, and sealants are installed. Report deficiencies and postpone testing until after the reported deficiencies are corrected.

Measure, adjust, and record the pressurization of each room, each zone, and each building by adjusting the supply, return, and exhaust airflows to achieve the indicated conditions.

Measure space pressure differential where pressure is used as the design criteria and measure airflow differential where differential airflow is used as the design criteria for space pressurization.

- For pressure measurements, measure and record the pressure difference between the intended spaces at the door with all doors in the space closed. Record the high-pressure side, low-pressure side, and pressure difference between each adjacent space.
- For applications with cascading levels of space pressurization, begin in the most critical space and work to the least critical space.
- Test room pressurization first, then zones, and finish with building pressurization.

To achieve indicated pressurization, set the supply airflow to the indicated conditions and adjust the exhaust and return airflow to achieve the indicated pressure or airflow difference.

For spaces with pressurization being monitored and controlled automatically, observe and adjust the controls to achieve the desired set point.

- Compare the values of the measurements taken to the measured values of the control system instruments and report findings.
- Check the repeatability of the controls by successive tests designed to temporarily alter the ability to achieve space pressurization. Test overpressurization and underpressurization, and observe and report on the system's ability to revert to the set point.

- For spaces served by variable-air-volume supply and exhaust systems, measure space pressurization at indicated airflow and minimum airflow conditions.

In spaces that employ multiple modes of operation, such as normal mode and emergency mode or occupied mode and unoccupied mode, measure, adjust, and record data for each operating mode.

Record indicated conditions and corresponding initial and final measurements. Report deficiencies.

- PROCEDURES FOR STAIR-TOWER PRESSURIZATION SYSTEM MEASUREMENTS AND ADJUSTMENTS

Before testing, observe the stair tower to verify that construction is complete. Verify the following:

- Walls and ceiling are free of unintended openings and are capable of achieving a pressure boundary.
- Firestopping and sealants are installed.
- Doors, door closers, and door gaskets are installed and adjusted.
- If applicable, window installation is complete.

Measure and record wind speed and direction, outside-air temperature, and relative humidity on each test day.

Test each stair tower as a single system. If multiple fans serve a single stair tower, operate the fans together.

Air Balance:

- Open the doors indicated to be open and measure, adjust, and record the airflow of each:
  - Stair-tower fan.
  - Air outlet supplying the stair tower.
- For ducted systems, measure the fan airflow by duct Pitot-tube traverse.

Pressurization Test:

- After air balancing is complete, perform stair-tower pressurization tests.
- Establish a consistent procedure for recording data throughout the entire test. Set the stair-tower side of the doors as the reference point and the floor side of the doors with positive pressure when

higher than the stair tower, and negative pressure when lower than the stair tower.

- With the HVAC systems operating in their normal mode of operation and the stair-tower pressurization systems off, measure and record the following:

  - Pressure difference across each stair-tower door with all doors in the stairwell closed.
  - Force necessary to open each door, using a spring-type scale.

- With the HVAC systems operating and the stair-tower pressurization system activated, perform the following:

  - Place building HVAC systems in their normal operating mode including equipment not used to implement smoke control, such as air-handling units, toilet exhaust fans, fan coil units, and similar equipment.
  - Measure and record the pressure difference across each stair-tower door with all doors in the stair tower closed. Adjust the stair-tower pressure relief to prevent overpressurization.
  - Use a spring scale to measure and record the force needed to open the door closest to the fan. With the initial door held in the open position, measure and record the pressure difference across each remaining closed stair-tower door.
  - Open additional doors (up to the number indicated) one at a time, and measure and record the pressure difference across each remaining closed stair-tower door after the opening of each additional door.
  - Open the doors indicated to be open and measure and record the direction and velocity through each of the open doors by a traverse of every 1 sq. ft. (0.093-sq. m) grid of door opening.
  - Calculate the average of the door velocity measurements. Compare the average velocity to the Contract Documents and governing code requirements.

- Repeat the pressurization tests with the smoke-control systems and the HVAC systems operating.
- Criteria for Acceptance:

  - The opening force on any door shall not exceed 30 lbf (133 N).
  - Code requirements.
  - <**Insert velocity, pressure, and other criteria.**>

Operational Tests:

- Check the proper activation of the stair-tower pressurization system(s) in response to all means of activation, both automatic and manual.
- Verify that each initiating occurrence produces the proper system response under each of the following modes of operation:

    - Normal.
    - Alarm.
    - Manual override of normal mode and alarm.
    - Return to normal.

- Verify that the smoke detector at the stair pressurization fan inlet de-energizes the fan and closes the damper at the fan.
- If standby power is provided for stair pressurization systems, test to verify that the stair pressurization systems operate while on both normal and standby power.
- Conduct additional tests required by authorities having jurisdiction.

Prepare a complete report of observations, measurements, and deficiencies.

- PROCEDURES FOR VIBRATION MEASUREMENTS

Use a vibration meter meeting the following criteria:

- Solid-state circuitry with a piezoelectric accelerometer.
- Velocity range of 0.1 to 10 inches per second (2.5 to 254 mm/s).
- Displacement range of 1 to 100 mils (0.0254 to 2.54 mm).
- Frequency range of at least 0 to 1000 Hz.
- Capable of filtering unwanted frequencies.

Calibrate the vibration meter before each day of testing.

- Use a calibrator provided with the vibration meter.
- Follow vibration meter and calibrator manufacturer's calibration procedures.

Perform vibration measurements when other building and outdoor vibration sources are at a minimum level and will not influence measurements of equipment being tested.

- Turn off equipment in the building that might interfere with testing.
- Clear the space of people.

Perform vibration measurements after air and water balancing and equipment testing is complete.

Clean equipment surfaces in contact with the vibration transducer.

Position the vibration transducer according to manufacturer's written instructions and to avoid interference with the operation of the equipment being tested.

Measure and record vibration on rotating equipment over 3 hp.

Measure and record equipment vibration, bearing vibration, equipment base vibration, and building structure vibration. Record velocity and displacement readings in the horizontal, vertical, and axial planes.

- Pumps:
  - Pump Bearing: Drive end and opposite end.
  - Motor Bearing: Drive end and opposite end.
  - Pump Base: Top and side.
  - Building: Floor.
  - Piping: To and from the pump after flexible connections.
- Fans and HVAC Equipment with Fans:
  - Fan Bearing: Drive end and opposite end.
  - Motor Bearing: Drive end and opposite end.
  - Equipment Casing: Top and side.
  - Equipment Base: Top and side.
  - Building: Floor.
  - Ductwork: To and from equipment after flexible connections.
  - Piping: To and from equipment after flexible connections.
- Chillers and HVAC Equipment with Compressors:
  - Compressor Bearing: Drive end and opposite end.
  - Motor Bearing: Drive end and opposite end.
  - Equipment Casing: Top and side.
  - Equipment Base: Top and side.
  - Building: Floor.
  - Piping: To and from equipment after flexible connections.

For equipment with vibration isolation, take floor measurements with the vibration isolation blocked solid to the floor and with the vibration isolation floating. Calculate and report the differences.

Inspect, measure, and record vibration isolation.

- Verify that vibration isolation is installed in the required locations.
- Verify that installation is level and plumb.
- Verify that isolators are properly anchored.

- For spring isolators, measure the compressed spring height, the spring OD, and the travel-to-solid distance.
- Measure the operating clearance between each inertia base and the floor or concrete base below. Verify that there is unobstructed clearance between the bottom of the inertia base and the floor.

- PROCEDURES FOR SOUND-LEVEL MEASUREMENTS

Specify sound-level testing if sound is a significant design criterion and sound treatment measures are used to achieve stringent criteria.

Perform sound-pressure-level measurements with an octave-band analyzer complying with ANSI S1.4 for Type 1 sound-level meters and ANSI S1.11 for octave-band filters. Comply with requirements in ANSI S1.13, unless otherwise indicated.

Calibrate sound meters before each day of testing. Use a calibrator provided with the sound meter complying with ANSI S1.40 and having NIST certification.

Use a microphone that is suitable for the type of sound levels measured. For areas where air velocities exceed 100 fpm (0.51 m/s), use a windscreen on the microphone.

Perform sound-level testing after air and water balancing and equipment testing are complete.

Close windows and doors to the space.

Perform measurements when the space is not occupied and when the occupant noise level from other spaces in the building and outside are at a minimum.

Clear the space of temporary sound sources so unrelated disturbances will not be measured. Position testing personnel during measurements to achieve a direct line-of-sight between the sound source and the sound-level meter.

Take sound measurements at a height approximately 48 inches (1200 mm) above the floor and at least 36 inches (900 mm) from a wall, column, and other large surface capable of altering the measurements.

Take sound measurements in dBA and in each of the 8 unweighted octave bands in the frequency range of 63 to 8000 Hz.

Take sound measurements with the HVAC systems off to establish the background sound levels and take sound measurements with the HVAC systems operating.

- Calculate the difference between measurements. Apply a correction factor depending on the difference and adjust measurements.

Edit number of locations and areas to be tested to suit Project. Use the size of Project and importance of acoustics as design criteria to determine number of locations to be tested.

Perform sound testing at <**Insert number**> locations on Project for each of the following space types. For each space type tested, select a measurement location that has the greatest sound level. If testing multiple locations for each space type, select at least one location that is near and at least one location that is remote from the predominant sound source.

- Private office.
- Open office area.
- Conference room.
- Auditorium/large meeting room/lecture hall.
- Classroom/training room.
- Patient room/exam room.
- Sound or vibration sensitive laboratory.
- Hotel room/apartment.
- Each space with a noise criterion of RC or NC 25 or lower.
- Each space with an indicated noise criterion of RC or NC 35 and lower that is adjacent to a mechanical equipment room or roof mounted equipment.
- Inside each mechanical equipment room.
- <**Insert other spaces.**>

- PROCEDURES FOR SMOKE-CONTROL SYSTEM TESTING

Before testing smoke-control systems, verify that construction is complete and verify the integrity of each smoke-control zone boundary. Verify that windows and doors are closed and that applicable safing, gasket, and sealants are installed. Report deficiencies and postpone testing until after the reported deficiencies are corrected.

Measure and record wind speed and direction, outside-air temperature, and relative humidity on each test day.

Measure, adjust, and record airflow of each smoke-control system with all fans that are a part of the system operating as intended by the design.

Measure, adjust, and record the airflow of each fan. For ducted systems, measure the fan airflow by duct Pitot-tube traverse.

After air balancing is complete, perform the following pressurization testing for each smoke-control zone in the system:

- Verify the boundaries of each smoke-control zone.
- With the HVAC systems in their normal mode of operation and smoke control not operating, measure and record the pressure difference across each smoke-control zone. Make measurements after closing doors that separate the zones. Make one measurement across each door. Clearly indicate the high and low pressure side of each door.
- With the system operating in the smoke-control mode and with each zone in the smoke-control system activated, perform the following:

    - Measure and record the pressure difference across each door that separates the smoke zone from adjacent zones. Make measurements with doors that separate the smoke zone from the other zones closed. Clearly indicate the high and low pressure side of the door. Doors that have a tendency to open slightly due to the pressure difference should have one pressure measurement made while held closed and another measurement made with the door open.
    - Continue to activate each separate zoned smoke-control system and make pressure difference measurements.
    - After testing a smoke zone's smoke-control system, deactivate the HVAC systems involved and return them to their normal operating mode before activating another zone's smoke-control system.
    - Verify that controls necessary to prevent excessive pressure differences are functional.

Operational Tests:

- Check the proper activation of each zoned smoke-control system in response to all means of activation, both automatic and manual.
- Check automatic activation in response to fire alarm signals received from the building's fire alarm and detection system. Initiate a separate alarm for each means of activation to ensure that the proper operation of the correct zoned smoke-control system occurs.
- Check and record the proper operation of fans, dampers, and related equipment as outlined below for each separate zone of the smoke-control system.

    - Fire zone in which a smoke-control system automatically activates.

- Type of signal that activates a smoke-control system, such as pull station, sprinkler water flow, or smoke detector.
- Smoke zone(s) where maximum mechanical exhaust to the outside is implemented and no supply air is provided.
- Positive pressure smoke-control zone(s) where maximum air supply is implemented and no exhaust to the outside is provided.
- Fan(s) "ON" as required to implement the smoke-control system. Multiple- or variable-speed fans should be further noted as "MAX. VOLUME" to verify that the intended control configuration is achieved.
- Fan(s) "OFF" as required to implement the smoke-control system.
- Damper(s) "OPEN" where maximum airflow must be achieved.
- Damper(s) "CLOSED" where no airflow should take place.
- Auxiliary functions to achieve the smoke-control system configuration such as changes or override of normal operating pressure and temperature-control set points.
- If standby power is provided for the smoke-control system, test to verify that the system functions while operating under both normal and standby power.

Conduct additional tests required by authorities having jurisdiction. Unless required by authorities having jurisdiction, perform testing without the use of smoke or products that simulate smoke.

Prepare a complete report of observations, measurements, and deficiencies.

- PROCEDURES FOR INDOOR-AIR QUALITY MEASUREMENTS

Indoor-air quality measuring is optional and not suitable for all projects. Evaluate its benefits and economic impact. Discuss this procedure with the client before including it in Project Construction Documents.

After air balancing is complete and with HVAC systems operating at indicated conditions, perform indoor-air quality testing.

Observe and record the following conditions for each HVAC system:

- The distance between the outside-air intake and the closest exhaust fan discharge, cooling tower, flue termination, or vent termination.
- Specified filters are installed. Check for leakage around filters.
- Cooling coil drain pans have a positive slope to drain.
- Cooling coil condensate drain trap maintains an air seal.
- Evidence of water damage.

- Insulation in contact with the supply, return, and outside air is dry and clean.

Measure and record indoor conditions served by each HVAC system. Make measurements at multiple locations served by the system if required to satisfy the following:

- Most remote area.
- One location per floor.
- One location for every 5000 sq. ft. (500 sq. m).

Measure and record the following indoor conditions for each location two times at two-hour intervals, and in accordance with ASHRAE Standard 113:

- Temperature.
- Relative humidity.
- Air velocity.
- Concentration of carbon dioxide (ppm).
- Concentration of carbon monoxide (ppm).
- Nitrogen oxides (ppm).
- Formaldehyde (ppm).

END OF SECTION 230800

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

INFORMATIVE ANNEX M
EXAMPLE CHECKLISTS

This annex provides an example of how to implement part of Guideline 1-200X. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X, and other applicable commissioning technical guidelines tailored to their specific projects. An example is NIBS Guideline 3-2006, Exterior Envelope Technical Requirements for the Commissioning Process.

This annex provides examples of checklists for the HVAC&R project requirements during Pre-Design, Design, Construction, and Occupancy and Operations Phases of project delivery that can be used for guidance for the commissioning practitioners applying the Commissioning Process.

Following is a listing by topic of the example checklists provided in this annex. These checklists follow the checklist format in Annex M of ASHRAE Guideline 0-2005.

Index of Example Checklists

1. Pre-Design Checklist: Mechanical Second Review
2. Design Checklist for the Mechanical Engineer's First Design Submittal Air-Handler
3. Air Handling Unit, CW & HW: AHU-1
4. Boiler, Hot Water: B-1
5. Centrifugal Chiller: C-1
6. Cooling Tower: CT-1
7. Coil, HW Heat: HWC-1
8. A. HVAC Piping: Insulation
   B. HVAC Piping: Insulation – Daily Checklist
9. A. Ductwork: Installation
   B. Ductwork: Installation – Daily Checklist
10. A. Ductwork: Insulation
    B. Ductwork: Insulation
11. Energy Recovery Wheel: ERW-1
12. Exhaust Fan: EF-1
13. Fan Coil Unit, CW & HW: FCU-1
14. Fire Damper: FD-1
15. Grilles, Registers & Diffusers: Diffusers
16. Humidifier, Steam: SH-1
17. HVAC Piping: Installation
18. VAV Box, Non Fan Powered w/ HW Heat: VAV-1
19. Pump, HVAC: P-1
20. Split System A/C Unit (coil portion): ACE-1
21. Split System A/C Unit (compressor portion): ACC-1

22. Unit Heater, HW: UH-1
23. Variable Speed Drive: VSD-1
24. VAV Box, Fan Powered w/ Electric Heat: FPVAV-1
25. Operations and Maintenance: Energy Efficiency Checklist

1. Pre-Design Checklist: Mechanical Second Review (As part of the Programming Architect's Second Review Submittal) ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Location of Information in the Programming Document	Response	
1	**Owner's Project Requirements**			
A	**Key Owner's Project Requirements**		Complete	
1	Project documentation requirements		Yes	No
2	Owner directives		Yes	No
3	Appropriate heating and cooling		Yes	No
4	Sustainability		Yes	No
5	Do the general requirements match OPR the original requirements? If not, has the OPR been revised? Justification document?		Yes	No
6	Has information been provided to the commissioning team to update the commissioning plan? What is the current revision number?		Yes	No
B	**Owner' Objectives**			
1	Is the final control plan, results of control workshop, and inter-operability report included with this review?		Yes	No
2	System accessibility and maintainability		Yes	No
3	Heating and cooling		Yes	No
4	Allowable tolerance in facility system operations		Yes	No
5	Energy efficiency goals		Yes	No
6	Environmental and sustainability goals		Yes	No
C	**Owner's General Needs**			
1	Adaptability for future changes without changing HVAC system and within initial budget		Yes	No
2	Mechanical rooms space and location coordinated with shops		Yes	No
3	Electrical / Communications		Yes	No
4	Benchmark Established for HVAC&R systems established		Yes	No
5	Constructability defined		Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

2. Design Checklist for the Mechanical Engineer's First Design Submittal
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	**Task Description**	**Location of Information: Document, Drawing, or draft Project Manual**	**Response**	
1	**Owner's Project Requirements**			
A	**Key Owner's Project Requirements**		Complete	
1	Commissioning Plan Updated, provide date and enclose with this submittal		Yes	No
2	Basis of Design for controls completed		Yes	No
3	Basis of Design for accessibility completed		Yes	No
4	Sustainability and LEED issues coordination addressed		Yes	No
5	Do the general HVAC&R requirements the current OPR requirements? Has justification been document and approved by owner's Project Manager?		Yes	No
6	Control format, BACnet requirements complete and documented		Yes	No
B	**Owner' Objectives**			
1	Preliminary mechanical room layout complete		Yes	No
2	Energy analysis meeting goal of 30% less than ASHRAE 90?		Yes	No
3	Single line diagrams developed for controls and systems		Yes	No
4	Report on safety factors and tolerance for facility system operations		Yes	No
5	Have chillers been sized and pre-order to meet occupancy goal		Yes	No
6	Environmental and sustainability initial design complete		Yes	No
C	**General Owner's Needs**			
1	Is current HVAC and control systems budget enclosed and within initial budget		Yes	No
2	Mechanical rooms space and location coordinated with shops		Yes	No
3	Has Electrical, Plumbing, Lighting and Communications coordination been completed?		Yes	No
4	Does the initial design meet all Benchmark Established for HVAC&R? Document?		Yes	No
5	Constructability and maintainability analysis completed		Yes	No

'No' Responses

Item	**Date**	**Reason for 'No' Response**

3. Air Handling Unit, CW & HW: AHU-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item		Task Description	Response	
1		**Delivery Book**		
A		**Model Verification**	Submitted	Delivered
	1	Manufacturer		
	2	Model		
	3	Serial Number	N/A	
	4	Cooling Capacity (MBH/gpm)	/	/
	5	Heating Capacity (MBH/gpm)	/	/
	6	Supply Air flow, Design / Minimum (cfm)	/	/
	7	Supply Fan Motor Power / Speed (hp / rpm)	/	/
	8	Return Air flow, Design / Minimum (cfm)		
	9	Return Fan Motor Power / Speed (hp / rpm)		
	10	Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B		**Physical Checks**		
	1	Unit is free from physical damage	Yes	No
	2	Coil surface areas are free of damage	Yes	No
	3	The air openings are sealed with plastic	Yes	No
	4	The water openings are sealed with plastic plugs	Yes	No
	5	All components present and in proper order	Yes	No
	6	All access doors are operable	Yes	No
	7	Installation and startup manual provided	Yes	No
	8	Unit tags affixed	Yes	No
2		**Construction Checklist**		
A		**Installation of AHU**		
	1	Unit secured as required by manufacturer and specifications	Yes	No
	2	Adequate clearance around unit for service	Yes	No
	3	All components accessible for maintenance	Yes	No
	4	Unit can be removed from the building	Yes	No
	5	Cooling coil drain pan slopes correctly	Yes	No
	6	Internal vibration isolators in good condition and shipping bolts are removed	Yes	No
	7	Belts are tight	Yes	No
	8	Unit labeled and is easy to see	Yes	No
B		**Chilled Water Piping**		
	1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
	2	Piping arranged for ease of unit/coil removal	Yes	No
	3	Piping supported as required by specifications	Yes	No
	4	Piping is clean	Yes	No
	5	Piping insulation is complete and installed as per specifications	Yes	No
	6	All valves and test ports are easily accessible	Yes	No
	7	Valve tags attached	Yes	No
C		**Hot Water Piping**		
	1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
	2	Piping arranged for ease of unit/coil removal	Yes	No
	3	Piping supported as required by specifications	Yes	No
	4	Piping is clean	Yes	No
	5	Piping insulation is complete and installed per specifications	Yes	No
	6	All valves and test ports are easily accessible	Yes	No
	7	Valve tags attached	Yes	No
D		**Ductwork**		
	1	Adequate locations available for testing and balancing of unit	Yes	No
	2	All dampers and sensors are accessible (access panels)	Yes	No

3	Outdoor and return air arrangement will not freeze coils, i.e. outdoor air and return air is adequately mixed before reaching coils	Yes	No
4	Vibration isolators installed	Yes	No
5	All dampers close tightly and stroke fully and easily	Yes	No
6	Ductwork is clean and free of debris	Yes	No
E	**Electrical**		
1	Local disconnect installed in accessible location	Yes	No
2	Motor rotation in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
5	VFD installed (if applicable)	Yes	No
F	**Controls - Installation**		
1	Control panel accessible and labeled properly	Yes	No
2	Temperature, humidity, pressure, and CO_2 sensors (as applicable) are installed and calibrated	Yes	No
3	Dampers actuators installed and calibration verified	Yes	No
4	Hot and chilled water actuators installed and calibration verified	Yes	No
5	Safety items installed and verified (freezestat, high pressure, motor overload, etc.)	Yes	No
G	**Mechanical - Startup**		
1	Unit is clean	Yes	No
2	Internal isolators free to move	Yes	No
3	Fans and motors lubricated and aligned	Yes	No
4	Fan belts have proper tension and are in good condition	Yes	No
5	Protective shrouds for fans and belts in place and secure	Yes	No
6	Terminal unit dampers manually opened or are controllable and open	Yes	No
7	Filters installed properly (no bypass air) and are clean	Yes	No
8	System starts and runs without any unusual noise or vibration	Yes	No
9	Manufacturer's startup checklist completed and attached	Yes	No
H	**Controls – Startup**		
1	Cooling sequence of control verified	Yes	No
2	Heating sequence of control verified	Yes	No
3	Warm-up sequence of control verified	Yes	No
4	Cool-down sequence of control verified	Yes	No
5	Economizer sequence of control verified	Yes	No
6	Unoccupied sequence of control verified	Yes	No
I	**TAB**		
1	Filters and coils are clean	Yes	No
2	Motor rotation verified - each motor	Yes	No
3	Motor voltage and amps verified - each phase of each motor	Yes	No
4	Fan RPM verified - each fan	Yes	No
5	Entering and leaving cooling coil air temperatures (°F)	/	/
6	Entering and leaving heating coil temperatures (°F)	/	/
7	Entering and leaving chilled water temperatures (°F)	/	/
8	Entering and leaving hot water temperatures (°F)	/	/
9	Coil flow and air/water pressure drops verified - each coil	Yes	No

Item	Date	Reason for 'No' Response

'No' Responses

4. Boiler, Hot Water: B-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item		Task Description	Response	
1		**Delivery Book**		
A		**Model Verification**	Submitted	Delivered
	1	Manufacturer		
	2	Model		
	3	Serial Number	N/A	
	4	Total Heating Capacity (MBH)		
	5	Voltage / Phase / Frequency (V / - /Hz)	/ /	/ /
	6	Entering / Leaving Hot Water Temperature (°F)	/	/
B		**Physical Checks**		
	1	Unit is free from physical damage	Yes	No
	2	The water openings are sealed with plastic plugs	Yes	No
	3	All components present	Yes	No
	4	Installation and startup manual provided	Yes	No
	5	Unit tags affixed	Yes	No
2		**Construction Checklist**		
A		**Installation of Boiler**		
	1	Unit secured as required by manufacturer and specifications	Yes	No
	2	Adequate clearance around unit for service	Yes	No
	3	All components accessible for maintenance	Yes	No
	4	Unit can be removed from building	Yes	No
	5	Flue completely installed and properly sloped	Yes	No
	6	Unit labeled and is easy to see	Yes	No
B		**Piping**		
	1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
	2	Piping arranged for ease of unit removal	Yes	No
	3	Piping supported as required by specifications	Yes	No
	4	Piping is clean	Yes	No
	5	Piping insulation is complete and installed as per specifications	Yes	No
	6	Thermometers and pressure gauges on supply and return lines	Yes	No
	7	All valves and test ports are easily accessible	Yes	No
	8	Valve tags attached	Yes	No
C		**Electrical**		
	1	Local disconnect installed in accessible location	Yes	No
	2	All electrical connections are tight	Yes	No
	3	All electrical components are grounded	Yes	No
D		**Controls – Installation**		
	1	Control panel accessible and labeled properly	Yes	No
	2	Remote start and stop verified	Yes	No
	3	Hot water temperature reset signal verified (if applicable)	Yes	No
	4	Test ports installed near all control sensors	Yes	No
	5	Actuators installed and calibration verified	Yes	No
E		**Mechanical – Startup**		
	1	System flushed, filled, and air purged	Yes	No
	2	Burner adjusted to proper settings	Yes	No
	3	System starts and runs without any unusual noise or vibration	Yes	No
	4	Manufacturer's startup checklist completed and attached	Yes	No
	5	CO_2 and CO values from burner adjustment (ppm/ppm)	/	/
F		**Controls – Startup**		
	1	Low water switch operational	Yes	No
	2	Temperature sensors operational and calibrated	Yes	No

3	Flow switch operational	Yes	No
4	High pressure / temperature cut out operational	Yes	No
5	Unit operating sequence verified and correct	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

5. Centrifugal Chiller: C-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Capacity (tons)		
5	Condenser Fluid Type		
6	Condenser Fluid Flow rate (gpm)		
7	Chilled Fluid Type		
8	Chilled Fluid Flow Rate (gpm)		
9	Refrigerant Type		
10	Compressor Motor Power (kW)		
11	Compressor Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	Openings are sealed with plastic	Yes	No
3	All components present (cooler, condenser, compressor, motor, etc.)	Yes	No
4	Motor bearings are double sealed and permanently lubricated	Yes	No
5	Electrical disconnect is provided	Yes	No
6	Installation and startup manual provided	Yes	No
7	Unit tags affixed	Yes	No
2	**Construction Checklist**		
A	**Installation of Chiller**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	There is a minimum of 36 inches of clearance around entire unit	Yes	No
3	There is a minimum of 48 inches of clearance in front of starter or VFD	Yes	No
4	There is a minimum clearance of one unit length for tube pull space	Yes	No
5	All components are accessible for maintenance	Yes	No
6	Unit labeled and is easy to see	Yes	No
B	**Refrigerant**		
1	Full operating charge of refrigerant and oil	Yes	No
2	Unit factory leak tested and report is attached	Yes	No
3	Relief piped to outdoors	Yes	No
4	Refrigerant monitor installed and operational before refrigerant loaded	Yes	No
5	Drip leg and flex connector at unit connection to relief piping	Yes	No
C	**Electrical**		
1	Lugs tightened by chiller startup technician	Yes	No

2	Safety disconnect switch installed in an accessible location	Yes	No
3	Lug sizing matches wire size requirement	Yes	No
4	Primary and secondary fused control power transformer provided	Yes	No
5	Star-delta starter provided	Yes	No
6	AIC and Withstand ratings exceed available fault shown on electrical drawings	Yes	No
7	VFD installed (if applicable)	Yes	No
D	**Controls - Installation**		
1	Control panel accessible and labeled properly	Yes	No
2	All sensors are installed and calibrated	Yes	No
3	Safety items installed and verified	Yes	No
E	**Controls - Startup**		
1	Unit voltage and amps verified	Yes	No
2	Remote start and stop signal verified	Yes	No
3	Chilled water reset signal verified	Yes	No
4	Demand limiting signal verified	Yes	No
5	Unit "run" sequences verified	Yes	No
6	Unit "alarm" sequences verified	Yes	No
F	**Mechanical - Startup**		
1	Manufacturer's startup checklist completed and attached	Yes	No
2	The following safety controls are operational and have been verified:	!Shaded	!Shaded
3	Low chilled water temperature	Yes	No
4	High refrigerant pressure	Yes	No
5	Low oil flow protection	Yes	No
6	Loss of chilled water flow	Yes	No
7	Loss of condenser flow	Yes	No
8	Loss of refrigerant protection	Yes	No
9	Motor current overload	Yes	No
10	Phase reversal/unbalance/single phasing	Yes	No
11	Over/under voltage	Yes	No
12	Failure of water temperature sensor used by controller	Yes	No
13	Full load test to verify load limiting	Yes	No
14	System starts and runs without any unusual noise or vibration	Yes	No
G	**TAB**		
1	Chilled water strainer is clean	Yes	No
2	Evaporator pressure drop (ft)		
3	Chilled water flow rate (gpm)		
4	Condenser water strainer is clean	Yes	No
5	Condenser water pressure drop (ft)		
6	Condenser water flow rate (gpm)		

'No' Responses

Item	**Date**	**Reason for 'No' Response**

6. Cooling Tower: CT-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Cooling Capacity (MBH/gpm)	/	
5	Fan Speed / power (rpm / hp)	/	
6	Motor Power and Speed (hp / rpm)		
7	Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	The air openings are sealed with plastic	Yes	No
3	The water openings are sealed with plastic plugs	Yes	No
4	All components present (fans, pumps, fill, etc.)	Yes	No
5	All access doors are operable	Yes	No
6	Installation and startup manual provided	Yes	No
7	Unit tags affixed	Yes	No
2	**Construction Checklist**		
A	**Installation of Cooling Tower**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components accessible for maintenance	Yes	No
4	Unit location is clear of trees, rubbish, dust, etc. to prevent fouling	Yes	No
5	Vibration isolators installed and in good condition	Yes	No
6	Ladder reaches grade level	Yes	No
7	Unit labeled and is easy to see	Yes	No
B	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawings	Yes	No
2	Piping arranged for ease of unit removal	Yes	No
3	Piping supported as required by specifications	Yes	No
4	Piping is clean	Yes	No
5	Makeup water supply provided	Yes	No
6	All valves and test ports are easily accessible	Yes	No
7	Valve tags attached	Yes	No
8	Piping insulation complete and installed as per specifications	Yes	No
C	**Electrical**		
1	Local disconnect installed in an accessible location	Yes	No
2	Fan motor rotation in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components grounded	Yes	No
5	VFD installed (if applicable)	Yes	No
D	**Controls - Installation**		
1	Control panel accessible and labeled properly	Yes	No
2	All sensors (temperature, pressure, etc.) are installed and calibrated verified	Yes	No
3	Valve actuators installed and calibration verified	Yes	No
4	Safety items installed and verified (low water, high water, etc.)	Yes	No
E	**Mechanical - Startup**		
1	Tower basin filled	Yes	No
2	Sump strainers and nozzles are clean	Yes	No
3	Motors and gear box lubricated	Yes	No

4	Fan pitch adjusted	Yes	No
5	Critical frequencies identified, recorded, and programmed out of VFD	Yes	No
6	System start and runs without any unusual noise or vibration	Yes	No
7	Manufacturer's startup checklist completed and attached	Yes	No
F	**Controls - Startup**		
1	Sequence of control verified	Yes	No
2	High / low water alarms operational	Yes	No
3	VFD operational	Yes	No
4	Float switch, motorized valves, makeup water are operational	Yes	No
G	**Water Treatment - Startup**		
1	Galvanized surfaces passivated (if applicable)	Yes	No
2	Conductivity and pH controls operational	Yes	No
3	Makeup flow meter signal operational	Yes	No
4	Blow-down control operational	Yes	No
5	No-flow injection interlock operational	Yes	No
H	**TAB**		
1	Unit is free of unusual noise or vibration	Yes	No
2	Motor overloads verified	Yes	No
3	Motor rotation verified - each motor	Yes	No
4	Motor voltage and amps verified - each phase of each motor	Yes	No
5	Flow rate through tower verified	Yes	No
6	Water distributed evenly in hot water basin with flow at 50% - no dumping	Yes	No
7	Water distributed evenly in hot water basin with flow at 100%	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

7. Coil, HW Heat: HWC-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Equipment or Area Served		
5	Heating Capacity (MBH/gpm)	/	/
6	Piping Inlet/Outlet Diameter (in)	/	/
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	The water openings are sealed	Yes	No
3	Installation and startup manual provided	Yes	No
4	Unit tags affixed	Yes	No
5	Manufacturer's ratings readable/accurate	Yes	No
2	**Construction Checklist**		
A	**Installation of Reheat Coil**		

1	Unit secured as required by specifications	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components are accessible for maintenance	Yes	No
4	Unit can be removed from building	Yes	No
5	Unit is labeled and is easy to see	Yes	No
B	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping arranged for ease of unit removal	Yes	No
3	Piping supported as required by specifications	Yes	No
4	Piping is clean	Yes	No
5	Piping insulation complete and installed as per specifications	Yes	No
6	All valves and test ports are easily accessible	Yes	No
7	Valve tags attached	Yes	No
C	**Controls**		
1	Temperature sensor calibration verified	Yes	No
2	Hot water actuator calibration verified	Yes	No
3	Point-to-point connections of control wiring verified	Yes	No
4	Central system accurately represents conditions of unit	Yes	No
5	Heating sequence of control verified	Yes	No
D	**TAB**		
1	Entering and leaving coil air temperatures (°F)	/	/
2	Entering and leaving coil water temperatures	/	/
3	Coil flow and air/water pressure drops verified	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

8A. HVAC Piping: Insulation
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.
Step 3: Samples of installed ductwork will be periodically reviewed to verify compliance.

General Overall (total job) HVAC Piping Insulation Requirement

Item	Task Description	Response	
1	**System Checks**		
A	**Installation Checks**	Submitted	Delivered
1	Piping is clean, dry and free of damage prior to installation.	Yes	No
2	Pressure and leakage tests performed and reports have been submitted prior to insulation installation.	Yes	No
3	All chilled water piping is insulated with 1 1/2 inch thick fiberglass pipe insulation with vapor barrier except runouts to radiant cooling panels located beyond 1'-0" within room being served.	Yes	No
4	Secondary chilled water, low temperature chilled water (2 1/2 inch thick), fan coil drain piping (1/2" thick), and piping with electric trace freeze protection is insulated in the same manner as the chilled water pipes.	Yes	No
5	All chilled water pumps are insulated with a 1 1/2 inch thick rectangular box made of Manville 817 rigid fiberglass board having a density of 6 lb/ft^3 with a rated vinyl coated and embossed laminate vapor seal (ASJ) jacket.	Yes	No
6	The insulation box for the pump is open at top and bottom with a removable top to effect a complete insulation for each base mounted pump.	Yes	No

7	The pipe insulation sections are firmly butted together and the longitudinal seam of the vapor barrier is cemented with Foster No. 85-75.	Yes	No
8	End joints are sealed with a minimum of 3 inch wide factory furnished vapor barrier strips cemented with Foster No. 85-75.	Yes	No
9	All fittings, valves, strainers etc. is insulated as described in the specifications.	Yes	No
10	Exterior piping has a 0.016 inch aluminum jacket with moisture barrier lock seam and Gasco of equal factory applied fittings in lieu of glass cloth jackets. A sample is submitted.	Yes	No

Item	Date	Reason for 'No' Response

'No' Responses

8B. HVAC Piping: Insulation – Daily Checklist
ASHRAE - Guideline 1-200X Example Checklist

Checklist for Daily Progress

Instructions: 1: This form is completed daily by each work crew at the end of their shift, indicate crew/shift designation

2: Date and describe work completed in the appropriate section (1 for pre-installation and 2 for installation

3: Verify achievement of quality requirements by circling "Yes" or "No". For negative responses, complete Section 3.

1. Pre-insulation inspection by installer

DATE	Description of Work Performed (relate to drawings and number)	Checklist Items			Percent Complete	Initial
		A. Clean	B. Valves	C. Material		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		

A. Piping clean or cleaned before insulation installed
B. Valves and other accessory surfaces were clean
C. Insulation material inspected to assure it had not been damaged

2. Installation of Insulation Checklist by installer

DATE	Description of Work Performed (relate to drawings and drawing numbers)	Checklist Items			Percent Complete	Initial
		A. Thickness	B. Sealed	C. Vapor barrier		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		

A. Insulation thickness checked against project manual and is correct.
B. The pipe insulation sections are firmly butted together and the longitudinal seam of the vapor barrier is cemented with Foster No. 85-75.
C. All vapor barriers installed.

3. Conflicts (Attach sketches or other documentation, including resolutions support; all items in sections 1 and 2 to be noted in this section. In addition, any conflicts or non-compliance of any items on the general checklist (Checklist Number 8A) or items not on the checklist should be noted in this section. If Cx Team determines it is significant issues, items will be added to the daily checklist.)

Date	Description of Conflict	Resolution or Suggested Resolution	Resolved
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No

9A. Ductwork: Installation
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.
Step 3: Samples of installed ductwork will be periodically reviewed to verify compliance.

Item	Task Description	Response	
1	**System Checks**		
A	**Sheet Metal Ductwork Installation Checks**	Submitted	Delivered
1	Ductwork is clean and free of damage prior to installation.	Yes	No
2	Ductwork is installed in accordance with SMACNA HVAC Duct Construction Standards, 2005	Yes	No
3	All hat sections and standoff brackets are at the same height as the duct lining.	Yes	No
4	Access doors are installed in all casting, plenums, ductwork adjacent to fire dampers, automatic dampers, smoke dampers, and reheat coils, and as indicated on drawings.	Yes	No
5	The access doors on casings or housings open to the inside on the discharge side and to the outside on the suction side.	Yes	No
6	All galvanized sheet metal is separated from aluminum and copper with lead or felt gaskets.	Yes	No
7	Ductwork is structurally sound to prevent drumming and sagging.	Yes	No
8	All transverse and longitudinal joints are sealed.	Yes	No
9	All branch and tee connections are 45 degree.	Yes	No
10	All medium pressure branch and tee connections are expanded 30 degrees on at least three sides.	Yes	No
11	Ductwork meets static pressure requirements specified below and leakage class A for these pressures as defined by SMACNA HVAC Duct Construction Standards, 1985.	Yes	No
12	All ductwork except as noted in the specification is leak tested.	Yes	No
13	Elbows have an inside radius equal to a minimum of 3/4 of the width of the duct.	Yes	No
14	All square elbows and radius elbows larger than 18 inches have turning vanes.	Yes	No
15	All wall and floor penetrations are sealed.	Yes	No
16	Volume dampers are at minimum provided for each horizontal branch from vertical risers serving two or more floors and branches serving two or more outlets.	Yes	No
17	All equipment requiring maintenance is accessible (valves, junction boxes, etc.).	Yes	No
18	All duct openings temporary sealed to maintain duct system cleanliness.	Yes	No
19	Record drawings have been updated to reflect any changes made.	Yes	No
B	**Flexile Ductwork Installation Checks**		
1	Flexible ductwork is clean and free from damage prior to installation.	Yes	No
2	Flexible ductwork is free of sags and kinks.	Yes	No
3	Flexible ductwork is installed using extra heavy flexible duct straps.	Yes	No
4	The maximum length of flexible ductwork is 5 feet.	Yes	No

5	Flexible ductwork does not penetrate walls.	Yes	No
6	Flexible ductwork does not have 90 degree bends.	Yes	No
C	**Ductwork Type Static Pressure Classification Installation Checks**		
1	From fan discharge to and including vertical risers, +6 in. static pressure	Yes	No
2	Branch supply ductwork, +4 in. static pressure.	Yes	No
3	Branch supply ductwork from terminal to room outlet, +1 in. static pressure.	Yes	No
4	Exhaust/return ductwork, ± 1 in. static pressure.	Yes	No
5	All other ductwork, ± 2 in. static pressure.	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

9B. Ductwork: Installation – Daily Checklist
ASHRAE - Guideline 1-200X Example Checklist

Checklist for Daily Progress

Instructions: 1: This form is completed daily by each work crew at the end of their shift, indicate crew/shift designation

2: Date and describe work completed in the appropriate section (1 for pre-installation and 2 for installation

3: Verify achievement of quality requirements by circling "Yes" or "No". For negative responses, complete Section 3.

1. Pre-insulation inspection by installer

DATE	Description of Work Performed (relate to drawings and number)	Checklist Items			Percent Complete	Initial
		A. Clean	B. Flex	C. Less 5'		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		

A. Ductwork is clean and free of damage prior to installation.
B. Flexible ductwork is clean and free from damage prior to installation.
C. The maximum length of flexible ductwork is 5'.

2. Installation of Insulation Checklist by installer

DATE	Description of Work Performed (relate to drawings and drawing numbers)	Checklist Items			Percent Complete	Initial
		A. SMACNA	B. Drumming	C. Access Doors		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		

A. Ductwork is installed in accordance with SMACNA HVAC Duct Construction Standards, 2005
B. Ductwork is structurally sound to prevent drumming and sagging.
C. All required access doors installed

3. Conflicts (Attach sketches or other documentation, including resolutions support; all items in section 1 and 2 to be noted in this section. In addition, any conflicts or non-compliance of any items

on the general checklist (Checklist Number 9A) or items not on the checklist should be noted in this section. If Cx Team determines it is significant issues, items will be added to the daily checklist.)

Date	Description of Conflict	Resolution or Suggested Resolution	Resolved
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No

10A. Ductwork: Insulation
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.
Step 3: Samples of installed ductwork will be periodically reviewed to verify compliance.

Item	Task Description	Response	
1	**System Checks**		
A	**Installation Checks**	Submitted	Delivered
1	Ductwork is clean, dry and free of damage prior to insulation installation.	Yes	No
2	Insulation is clean and dry during installation and application of any finish.	Yes	No
3	Pressure and leakage tests performed and reports have been submitted prior to insulation installation.	Yes	No
4	All equipment requiring maintenance is accessible (valves, junction boxes, etc.).	Yes	No
5	Insulation is continuous through openings and sleeves in non-rated construction, and is butted tightly against the fire stop with butt joints taped in rated construction.	Yes	No
6	All insulation edges temporary sealed to maintain duct insulation cleanliness.	Yes	No
7	Insulation is removable at access panels with metal corner beads.	Yes	No
8	Insulation is omitted at all equipment name plates and/or data plates.	Yes	No
9	All outdoor intakes, housing, plenums from point of entry into the building to the fan or supply discharge and to exhaust duct from damper to outside and elsewhere be indicated on drawings are insulated with 1 1/2 inch rigid insulation board w/ vapor barrier.	Yes	No
11	All exposed conditioned supply ductwork within the building is insulated with 1 inch thick rigid insulation board with vapor barrier.	Yes	No
12	All non flexible ductwork insulation is fastened by applying Foster No. 85-20 adhesive in 4 inch wide continuous bands on 12 inch centers and further secured by welded mechanical pins applied on 12" center as specified.	Yes	No
13	All concealed flexible and round ductwork is insulated with 1 1/2 inch thick insulation and secured by the means of metal staples using the stitching methods of application and as detailed in the specifications.	Yes	No
14	All exterior corners are sealed with a 5 inch wide tape.	Yes	No
B	**Installation Checks - Flexible Ductwork**		
1	Flexible ductwork is clean and free from damage prior to installation.	Yes	No
2	Flexible ductwork is free of sags and kinks.	Yes	No
3	Flexible ductwork is installed using extra heavy flexible duct straps.	Yes	No
4	The maximum length of flexible ductwork is 5 feet.	Yes	No
5	Flexible ductwork does not penetrate walls.	Yes	No
6	Flexible ductwork does not have 90-degree bends.	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

10B. Ductwork: Insulation – Daily Checklist
ASHRAE - Guideline 1-200X Example Checklist

Checklist for Daily Progress

Instructions: 1: This form is completed daily by each work crew at the end of their shift, indicate crew/shift designation

2: Date and describe work completed in the appropriate section (1 for pre-installation and 2 for installation

3: Verify achievement of quality requirements by circling "Yes" or "No". For negative responses, complete Section 3.

1. Pre-insulation inspection by installer

DATE	Description of Work Performed (relate to drawings and number)	Checklist Items			Percent Complete	Initial
		A. Clean	B. Leak Tested	C. Material		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		

A. Ductwork clean or cleaned before insulation installed
B. All sections leak tested prior to applying insulation
C. Insulation material inspected to assure it had not been damaged

2. Installation of Insulation Checklist by installer

DATE	Description of Work Performed (relate to drawings and drawing numbers)	Checklist Items			Percent Complete	Initial
		A. Thickness	B. Sealed	C. Vapor barrier		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		
		Yes/No	Yes/No	Yes/No		

A. Insulation thickness checked against project manual and is correct.
B. All Flex duct installed per drawing and no runs more than five feet
C. All vapor barriers installed.

3. Conflicts (Attach sketches or other documentation, including resolutions support; all items in sections 1 and 2 to be noted in this section. In addition, any conflicts or non-compliance of any items on the general checklist (Checklist Number 10A) or items not on the checklist should be noted in this section. If Cx Team determines it is significant issues, items will be added to the daily checklist.)

Date	Description of Conflict	Resolution or Suggested Resolution	Resolved
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No
			Yes/No

11. Energy Recovery Wheel: ERW-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Exhaust air flow (cfm)		
5	Supply air flow (cfm)		
6	Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	The air openings are sealed with plastic	Yes	No
3	All components present and in proper order	Yes	No
4	All access doors are operable	Yes	No
5	Installation and startup manual provided	Yes	No
6	Unit identification attached and visible	Yes	No
2	**Construction Checklist**		
A	**Installation of Energy Recovery Wheel**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	Purge section in correct direction	Yes	No
3	Adequete clearance around unit for service	Yes	No
4	All components accessible for maintenance	Yes	No
5	Unit can be removed from building	Yes	No
6	Unit identification attached and visible	Yes	No
B	**Electrical**		
1	Local disconnect installed in an accessible location	Yes	No
2	Wheel rotation in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
5	VFD installed (if applicable)	Yes	No
C	**Ductwork**		
1	Duct work is attached according to manufacturer recommendations	Yes	No
2	Inlets and outlets of energy recovery wheel are free of ductwork blockage	Yes	No
3	Structural support for ductwork is independent of wheel unit	Yes	No
4	Ductwork placement allows unrestricted airflow and clear view of rotation labeling	Yes	No
5	Access doors have been supplied in each duct near the unit	Yes	No
6	Adequete locations for testing and balancing of unti	Yes	No
7	All dampers and sensors are accesible (access doors)	Yes	No
8	Ductwork is clean and free of debris	Yes	No
D	**Controls - Installation**		
1	Control panel accessible and labeled properly	Yes	No
2	Temperature, pressure, and CO_2 sensors (as applicable) are installed and calibrated	Yes	No
3	Safety items installed and verified (freezestat, high pressure, motor overload, etc.)	Yes	No
E	**Mechanical - Startup**		
1	System clean	Yes	No
2	Wheel lubricated and aligned	Yes	No
3	Wheel belts have proper tension and are in good condition	Yes	No
4	Seals have been adjusted according to manufacturer specifications	Yes	No
5	Duct installation conforms to airflow labeling	Yes	No
6	System starts and runs without any unusual noise or vibration	Yes	No
7	Manufacturer's startup checklist completed and attached	Yes	No
F	**Controls - Startup**		

1	Warm-up sequence of control verified	Yes	No
2	Cool-down sequence of control verified	Yes	No
3	Economizer sequence of control verified	Yes	No
4	Unoccupied sequence of control verified	Yes	No
G	**TAB**		
1	Motor voltage and amps verified	Yes	No
2	Wheel speed, design/actual (rpm)	/	/
3	Pressure drop between outside air and return air is large enough	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

12. Exhaust Fan: EF-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Fan Type		
5	Capacity / Static Pressure (cfm / in. wg)	/	/
6	Motor Power / Speed (hp / rpm)	/	/
7	Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	The air openings are sealed with plastsic	Yes	No
3	All components present (belt guard, motor, damper, spring isolators, etc.)	Yes	No
4	Installation and startup manual provided	Yes	No
5	Unit tags affixed	Yes	No
2	**Construction Checklist**		
A	**Installation of Exhaust Fan**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components accessible for maintenance	Yes	No
4	Unit can be removed from building	Yes	No
5	Shipping bolts have been removed (if applicable)	Yes	No
6	Belts are tight (if applicable)	Yes	No
7	Back draft damper installed and moves freely	Yes	No
8	Protective shrouds for fan and belts in place and secure	Yes	No
9	Unit labeled and is easy to see	Yes	No
B	**Ductwork**		
1	Adequate locations available for testing and balancing unit	Yes	No
2	All dampers and sensors are accessible (access panels)	Yes	No
3	Vibration isolators installed	Yes	No
4	All dampers close tightly and stroke fully and easily	Yes	No
5	Ductwork is clean and free of debris	Yes	No

C	Electrical		
1	Safety disconnect installed in an accessible location	Yes	No
2	Motor rotation is in correct direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
D	**Controls - Installation**		
1	Control panel accessible and labeled properly	Yes	No
2	Dampers actuators installed and calibration verified	Yes	No
3	Safety items installed and verified (high pressure, motor overload, etc.)	Yes	No
E	**Mechanical - Startup**		
1	Unit is clean	Yes	No
2	Internal isolators free to move	Yes	No
3	Fan and motor lubricated and aligned	Yes	No
4	Fan belts have proper tension and are in good condition (if applicable)	Yes	No
5	System starts and runs without any unusual noise or vibration	Yes	No
6	Manufacturer's startup checklist completed and attached	Yes	No
F	**Controls - Startup**		
1	Remote start/stop from central system verified	Yes	No
2	Sequence of control is correct (e.g., interlock)	Yes	No
G	**TAB**		
1	Air flow, design / actual (cfm)	/	/
2	Pressure drop, design / actual (in. wg)	/	/
3	Fan rotation is in the proper direction	Yes	No
4	Motor overloads verified	Yes	No
5	Motor voltage and amps verified - each phase	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

13. Fan Coil Unit, CW & HW: FCU-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Capacity / Static Pressure (cfm / in. wg)	/	/
5	Fan Motor Power (hp)		
6	Fan Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
7	Total / Sensible Cooling Capacity (MBH)	/	/
8	Cooling Fluid Flow / Pressure Drop (gpm / ft wg)	/	/
9	Total Heating Capacity (MBH)		
10	Heating Fluid Flow / Pressure Drop (gpm / ft wg)	/	/
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No

2	Coil surface areas are free of damage	Yes	No
3	The water openings are sealed with plastic plugs	Yes	No
4	All components present	Yes	No
5	Installation and startup manual provided	Yes	No
6	Unit tags affixed	Yes	No
2	**Construction Checklist**		
A	**Installation of Fan Coil Unit**		
1	Unit supported using adequately sized mounting anchors	Yes	No
2	Metal to metal connections eliminated to prevent noise problems	Yes	No
3	Adequate clearance around unit for service	Yes	No
4	All components are accessible for maintenance	Yes	No
5	Unit can be removed from building	Yes	No
6	Unit labeled and is easy to see	Yes	No
B	**Chilled Water Piping**		
1	Condensate piping properly installed (trapped and run to a drain)	Yes	No
2	P/T ports installed across the cooling coil	Yes	No
3	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
4	Piping arranged for ease of unit/coil removal	Yes	No
5	Piping supported as required by specifications	Yes	No
6	Piping is clean	Yes	No
7	Piping insulation complete and installed as per specifications	Yes	No
8	All valves and test ports are easily accessible	Yes	No
9	Valve tags attached	Yes	No
C	**Hot Water Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping arranged for ease of unit/coil removal	Yes	No
3	Piping is supported as required by specifications	Yes	No
4	Piping is clean	Yes	No
5	Piping insulation complete and installed as per specifications	Yes	No
6	All valves and test ports are easily accessible	Yes	No
7	Valve tags attached	Yes	No
D	**Ductwork**		
1	Adequate locations available for testing and balancing of unit	Yes	No
2	All dampers and sensors are accessible (access doors)	Yes	No
3	All dampers close tightly and stroke fully and easily	Yes	No
4	Filter is clean	Yes	No
5	Filter is properly installed (air bypassing the filter is prevented)	Yes	No
6	Ductwork is clean and free of debris		
E	**Electrical**		
1	Local disconnect installed in an accessible location	Yes	No
2	Motor rotation in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
F	**Controls - Installation**		
1	Control panel accessible and labeled properly	Yes	No
2	Room thermostat installed and calibration verified	Yes	No
3	Chilled and hot water actuators installed and calibration verified	Yes	No
G	**Controls - Startup**		
1	Unit operation accurately represented on main system	Yes	No
2	Cooling sequence of control verified	Yes	No
3	Heating sequence of control verified	Yes	No
H	**TAB**		
1	Filters and coils are clean	Yes	No
2	Motor rotation verified	Yes	No
3	Motor overloads verified	Yes	No
4	Motor voltage and amps verified - each phase	Yes	No
5	Entering and leaving cooling coil air temperature (°F)	/	/

7	Entering and leaving heating coil air temperature (°F)	/	/
8	Entering and leaving chilled water temperature (°F)	/	/
9	Entering and leaving hot water temperature (°F)	/	/
10	Coil flow and air/water pressure drops verified - each coil	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

14. Fire Damper: FD-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Style		
4	Width (in.)		
5	Height (in.)		
6	Orientation		
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	All components/accessories present	Yes	No
3	Installation manual provided	Yes	No
2	**Construction Checklist**		
A	**Installation of Fire Damper**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	Adequate clearance around unit for maintenance	Yes	No
3	Unit mounted in correct orientation	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

15. Grilles, Registers & Diffusers: Diffusers
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item		Task Description	Response	
1		**Delivery Book**		
A		**Model Verification**	Submitted	Delivered
	1	Manufacturer		
	2	Model		
	3	Frame		
	4	Color		
	5	Neck Width (in.)		
	6	Neck Height (in.)		
B		**Physical Checks**		
	1	Unit is free from physical damage	Yes	No
	2	All components/accessories present	Yes	No
	3	Installation manual provided	Yes	No
2		**Construction Checklist**		
A		**Installation of Grille/Register**		
	1	Unit secured as required by manufacturer and specifications	Yes	No
	2	Any surface blemishes have been touched up	Yes	No
	3	Design CFM confirmed	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

16. Humidifier, Steam: SH-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item		Task Description	Response	
1		**Delivery Book**		
A		**Model Verification**	Submitted	Delivered
	1	Manufacturer		
	2	Model		
	3	Serial Number	N/A	
	4	Steam Output Capacity (lb/hr)		
	5	Steam Input Capacity (lb/hr)		
	6	Inlet Steam Maximum Pressure (psig)		
B		**Physical Checks**		
	1	Unit is free from physical damage	Yes	No
	2	All components present	Yes	No
	3	Installation and startup manual provided	Yes	No
	4	Unit tags affixed	Yes	No
2		**Construction Checklist**		
A		**Installation of Humidifier**		

1	Unit secured as required by manufacturer and specifications	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components are accessible for maintenance	Yes	No
4	Unit can be removed from building	Yes	No
5	Unit located below duct level for good drainage	Yes	No
6	Dispersion tube located as per manufacturer's recommendations	Yes	No
7	Unit labeled and is easy to see	Yes	No
B	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping arranged for ease of unit removal	Yes	No
3	Piping sloped for complete drainage	Yes	No
4	Piping supported as required by specifications	Yes	No
5	Piping is clean and free from leaks	Yes	No
6	All valves and test ports are easily accessible	Yes	No
7	Valve tags attached	Yes	No
C	**Controls - Installation**		
1	Air flow sensor installed and calibration verified	Yes	No
2	Duct high limit humidistat installed and calibration verified	Yes	No
D	**Controls - Startup**		
1	Sequence of control verified	Yes	No
2	Unit operation accurately represented on main system	Yes	No
3	Airflow sensor operation verified	Yes	No
4	Duct high limit humidistat operation verified	Yes	No

'No' Responses

Item	**Date**	**Reason for 'No' Response**

17. HVAC Piping: Installation
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.
Step 3: Samples of installed HVAC piping will be periodically reviewed to verify compliance.

Item	**Task Description**	**Response**	
1	**System Checks**		
A	**Installation Checks**	Submitted	Delivered
1	Piping is clean and free of damage prior to installation.	Yes	No
2	Piping is free to expand and contract without noise or damage to hangers, joints, or the building.	Yes	No
3	Piping is installed with sufficient pitch and arranged in a manner to ensure drainage and venting of the entire system.	Yes	No
4	Manual air vents are provided at high points in close water systems.	Yes	No
5	Changes in pipe sizes are made with the proper size reducing fittings, reducing fittings, reducing elbow or reducing tees. Bushings are not allowed.	Yes	No
6	All piping supports and hangers meet criteria set in Section 15140 of the specifications.	Yes	No
7	All fittings meet specification requirements.	Yes	No
8	All equipment requiring maintenance is accessible (valves, junction boxes, etc.).	Yes	No

9	Piping does not block access to equipment that is part of this system or another system (e.g., air terminal units).	Yes	No
10	Piping is installed in a manner to ensure that insulation will not contact adjacent surfaces.	Yes	No
11	All pipe openings are temporarily sealed to maintain piping system cleanliness.	Yes	No
12	Record drawings have been updated to reflect any changes made.	Yes	No
13	Nipples are made of the same material as the pipe.	Yes	No
14	Connections between copper and steel pipes are made with dielectric fittings.	Yes	No
15	A union is provided ahead of each screwed valve, trap, or strainer, and on each side of each piece of equipment and whatever needed to dismantle piping.	Yes	No
16	Mechanical coupling if used is only used for piping and locations as described in the specification section 15060.	Yes	No
17	The chilled water system is installed with high pressure fittings, flanges and unions.	Yes	No
18	Auxiliary drain valves are provided at all low points in hose bib piping to facilitate seasonal draining.	Yes	No
19	A clearance of 8 ft 2 in. is maintained throughout the parking structure. Walker's drawings have been consulted for exact location of pipe spaces, ceilings heights, and other details before installing piping.	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

18. Split System A/C Unit (compressor portion): ACC-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Size (in)		
5	Max/Min Airflow (cfm)		
6	Heating Capacity (MBH/gpm)	/	/
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	The air openings are sealed with plastic	Yes	No
3	The water openings are sealed with plastic plugs	Yes	No
4	The airflow sensing tubing is plugged	Yes	No
5	The grommets for the airflow sensing tubing are secure	Yes	No
6	The enclosure for the DDC control panel is in the proper location	Yes	No
7	Installation and startup manual provided	Yes	No
8	Unit tags affixed	Yes	No
9	Manufacturer's ratings readable/accurate	Yes	No
2	**Construction Checklist**		
A	**Hanging**		
1	Unit is supported as required by manufacturer and specifications	Yes	No
2	Metal to metal connections eliminated to prevent noise problems	Yes	No

3	Adequate clearance around control panel for maintenance	Yes	No
4	Clear access below unit for easy maintenance	Yes	No
5	Unit labeled and is easy to see	Yes	No
6	Box openings temporarily sealed to maintain system cleanliness	Yes	No
B	**Ductwork**		
1	Balancing damper present on inlet duct	Yes	No
2	Sufficient length of straight ductwork installed upstream of unit	Yes	No
3	Downstream ductwork free of transitions for sufficient length	Yes	No
4	All components are accessible for maintenance	Yes	No
5	Flexible connector (vibration isolator) installed on inlet duct to avoid noise problems from metal to metal contact	Yes	No
6	Flex duct (if used) is installed in a way that avoids forming kinks on both inlet and outlet ductwork	Yes	No
C	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping is arranged for ease of unit/coil removal	Yes	No
3	Piping supported as required by specifications	Yes	No
4	Piping is clean	Yes	No
5	Piping insulation is complete and installed as per specifications	Yes	No
6	All valves and test ports are easily accessible	Yes	No
7	Valve tags attached	Yes	No
D	**Controls - Installation**		
1	Temperature sensor calibration verified	Yes	No
2	Airflow sensor calibration verified	Yes	No
3	Point-to-point connections of control wiring verified	Yes	No
4	Central system accurately represents conditions of unit	Yes	No
E	**Controls - Startup**		
1	Cooling/heating sequence of control verified	Yes	No
2	Warm-up/cool-down sequence of control verified	Yes	No
3	Unoccupied sequence of control verified	Yes	No
F	**TAB**		
1	Minimum airflow (cfm) (design/measured)	/	/
2	Maximum airflow (cfm) (design/measured)	/	/
3	Entering and leaving coil air temperatures (°F)	/	/
4	Entering and leaving coil water temperatures (°F)	Yes	No
5	Coil flow and air/water pressure drops verified	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

19. Pump, HVAC: P-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		

2	Model		
3	Serial Number	N/A	
4	Pump Type		
5	Impeller diameter (in)		
6	Inlet / Outlet Sizes (in)	/	/
7	Capacity / Head (gpm / ft wg)	/	/
8	Motor Speed / Power (rpm / hp)	/	/
9	Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	All components present	Yes	No
3	The water openings are sealed with plastic plugs	Yes	No
4	Unit tags affixed	Yes	No
5	Installation and startup manual provided	Yes	No
7	Manufacturer's ratings readable/accurate	Yes	No
2	**Construction Checklist**		
A	**Installation of Pump**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components accessible for maintenance	Yes	No
4	Unit can be removed from building	Yes	No
5	Unit labeled and is easy to see	Yes	No
B	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping arranged for ease of unit removal	Yes	No
3	Shut-off valves and unions installed on inlet and outlet of pump	Yes	No
4	Pressure gauges installed on inlet and outlet of pump	Yes	No
5	Piping supported as required by specifications	Yes	No
6	Piping is clean	Yes	No
7	Piping insulation complete and installed as per specifications	Yes	No
8	All valves and test ports are easily accessible	Yes	No
9	Valve tags attached	Yes	No
C	**Electrical**		
1	Safety disconnect installed in an accessible location	Yes	No
2	Motor rotation in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
D	**Mechanical - Startup**		
1	Unit checked, aligned, and certified prior to startup and report submitted	Yes	No
2	Unit and motor lubricated before startup	Yes	No
3	Pump shaft rotates easily with power turned off	Yes	No
4	System starts and runs without any unusual noise or vibration	Yes	No
5	Manufacturer's startup checklist completed and attached	Yes	No
E	**TAB**		
1	Flow Rate, gpm		
2	Inlet pressure (ft) / Outlet pressure (ft)	/	/
3	Motor rotation in the proper direction	Yes	No
4	Motor overload verified	Yes	No
5	Motor voltage and amps verified - each phase	Yes	No
6	Start-up strainer removed (after 24 hours)	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

20. Split System A/C Unit (coil portion): ACE-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Airflow (cfm)		
5	Fan Motor Power (hp)		
6	Fan Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
7	Total Cooling Capacity (MBH)		
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	All components present	Yes	No
3	The refrigerant line openings are sealed	Yes	No
4	Installation and startup manual provided	Yes	No
5	Unit tags affixed	Yes	No
2	**Construction Checklist**		
A	**Installation of Split System Coil**		
1	Unit supported using adequately sized mounting anchors	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components are accessible for maintenance	Yes	No
4	Unit can be removed from building	Yes	No
5	Condensate drain piping un-trapped and runs to open sight drain	Yes	No
6	Unit labeled and is easy to see	Yes	No
B	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping arranged for ease of unit removal	Yes	No
3	Piping supported as required by specifications	Yes	No
4	Refrigerant lines connected to indoor and outdoor units	Yes	No
5	Piping is clean and free from leaks	Yes	No
6	Piping insulation is complete and installed as per specifications	Yes	No
7	All valves and test ports are easily accessible	Yes	No
8	Valve tags attached	Yes	No
9	Unit filled with correct refrigerant	Yes	No
C	**Electrical**		
1	Local disconnect installed in an accessible location	Yes	No
2	Fan motor rotation in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
D	**Controls - Installation**		
1	Room thermostat installed and calibration verified	Yes	No
2	Control wiring provided to outdoor (compressor) unit	Yes	No
3	Communication with outdoor unit verified	Yes	No
E	**Controls - Startup**		
1	Cooling sequence of control verified	Yes	No
2	System starts and runs with no unusual noise or vibration	Yes	No
3	Manufacturer's startup checklist completed and attached	Yes	No
F	**TAB**		

1	Filters installed and are clean	Yes	No
2	Entering and leaving air temperatures (°F)	/	/
3	Airflow (cfm)	/	/

'No' Responses

Item	Date	Reason for 'No' Response

21. Split System A/C Unit (compressor portion): ACC-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Airflow (cfm)		
5	Ambient Temperature (°F)		
6	Fan Motor Power (hp)		
7	Fan Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	All components present	Yes	No
3	The refrigerant line openings are sealed	Yes	No
4	Installation and startup manual provided	Yes	No
5	Unit tags affixed	Yes	No
2	**Construction Checklist**		
A	**Installation of Split System Compressor**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components are accessible for maintenance	Yes	No
4	Unit labeled and is easy to see	Yes	No
B	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping arranged for ease of unit removal	Yes	No
3	Piping supported as required by specifications	Yes	No
4	Refrigerant lines connected to indoor and outdoor units	Yes	No
5	Piping is clean and free from leaks	Yes	No
6	Piping insulation is complete and installed as per specifications	Yes	No
7	All valves and test ports are easily accessible	Yes	No
8	Valve tags attached	Yes	No
9	Unit filled with correct refrigerant	Yes	No
C	**Electrical**		
1	Local disconnect installed in an accessible location	Yes	No
2	Fan motor rotation in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
D	**Controls - Installation**		

1	Control wiring provided to indoor (coil) unit	Yes	No
2	Communication with indoor unit verified	Yes	No
E	**Controls - Startup**		
1	Safety items operational (high pres., low pres., discharge temp. switch)	Yes	No
2	System starts and runs with no unusual noise or vibration	Yes	No
3	Manufacturer's startup checklist completed and attached	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

22. Unit Heater, HW: UH-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial number	N/A	
4	Fan Motor Power (hp)		
5	Fan Motor Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
6	Total Heating Capacity (MBH)		
7	Heating Fluid Flow / Pressure Drop (gpm / ft wg)	/	/
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	All components present	Yes	No
3	The water openings are sealed with plastic plugs	Yes	No
4	Manufacturer's data readable/accurate	Yes	No
5	Unit identification attached and visible	Yes	No
2	**Construction Checklist**		
A	**Installation of Unit Heater**		
1	Unit supported using adequately sized mounting anchors	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components accessible for maintenance	Yes	No
4	Unit can be removed from building	Yes	No
5	Unit identification attached and visible	Yes	No
B	**Piping**		
1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
2	Piping arranged for ease of unit removal	Yes	No
3	Piping supported as required by specifications	Yes	No
4	Piping is clean	Yes	No
5	Piping insulation complete and installed as per specifications	Yes	No
6	All valves and test ports are easily accessible	Yes	No
C	**Electrical**		
1	Local disconnect installed in an accessible location	Yes	No
2	Motor rotation in the proper direction	Yes	No

3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
D	**Controls**		
1	Room thermostat installed and calibration verified	Yes	No
2	Hot water actuator calibration verified	Yes	No
3	Heating sequence of control verified	Yes	No
4	Valve tags are attached	Yes	No
E	**TAB**		
1	Motor rotation in the proper direction	Yes	No
2	Motor overloads verified	Yes	No
3	Motor voltage and amps verified - each phase	Yes	No
4	Entering and leaving air temperatures (°F)	/	/
5	Flow and air/water pressure drops verified	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

23. Variable Speed Drive: VSD-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Service Area		
5	Maximum Capacity (amps)		
6	Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	All components present	Yes	No
3	Installation and startup manual provided	Yes	No
4	Wiring schematics (electrical & controls) for this application attached	Yes	No
5	Unit tags affixed	Yes	No
6	Manufacturer's ratings readable/accurate	Yes	No
2	**Construction Checklist**		
A	**Installation of VSD**		
1	Unit secured as required by manufacturer and specifications	Yes	No
2	Adequate clearance around unit for service	Yes	No
3	All components are accessible for maintenance	Yes	No
4	Unit can be removed from building	Yes	No
5	Unit labeled and is easy to see	Yes	No
6	Wiring schematic inside enclosure and includes bypass section	Yes	No
B	**Electrical**		
1	Drive to motor leads are in grounded metal conduit	Yes	No
2	All electrical connections are tight	Yes	No
3	All electrical components are grounded	Yes	No

C	**Controls - Installation**		
1	Control panel accessible and labeled properly	Yes	No
2	Low voltage control signals are shielded and in own conduit	Yes	No
3	Auxiliary safeties (F/A shutdown, etc.) are installed and operational	Yes	No
4	Analog output to control unit is "isolated type	Yes	No
D	**Electrical - Pre-Startup Checks**		
1	Motor full load amps less than max rating, design / actual	/	/
2	Input voltage, design / actual (within 10% of rating)	/	/
3	All grounds verified	Yes	No
4	All fuses verified	Yes	No
E	**Electrical - Startup**		
1	VSD properly powers up	Yes	No
2	Stop button works	Yes	No
3	Motor rotation is in the proper direction	Yes	No
4	Minimum and maximum speeds reached using remote command	Yes	No
5	"Accel" and "Decel" adjustments are made within the drive and do not depend on ramping signal from the DDC controls	Yes	No
6	VSD restarts automatically	Yes	No
7	No disconnect on load side of VSD	Yes	No
8	Critical frequencies have been programmed out of VSD (if applicable)	Yes	No
9	Motor runs in bypass mode while servicing or removing unit	Yes	No
10	Motor overload protection and phase loss protection provided during bypass mode	Yes	No
11	System starts and runs without any unusual noise or vibration	Yes	No
12	Manufacturer's startup checklist completed and attached	Yes	No

'No' Responses

Item	Date	Reason for 'No' Response

24. VAV Box, Fan Powered w/ Elect Heat: FPVAV-1
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No, or fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item	Task Description	Response	
1	**Delivery Book**		
A	**Model Verification**	Submitted	Delivered
1	Manufacturer		
2	Model		
3	Serial Number	N/A	
4	Size (in)		
5	Max/Min Airflow (cfm)	/	/
6	Heating Capacity (MBH/kW)	/	/
7	Total Static Pressure (in. w.g.)		
8	Fan Power / Speed (hp / rpm)	/	/
9	Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
B	**Physical Checks**		
1	Unit is free from physical damage	Yes	No
2	The air openings are sealed with plastic	Yes	No
3	The airflow sensing tubing is plugged	Yes	No
4	The grommets for the airflow sensing tubing are secure	Yes	No

5	The enclosure for the DDC control panel is in the proper location	Yes	No
6	Installation and startup manual provided	Yes	No
7	Unit tags affixed	Yes	No
8	Manufacturer's ratings readable/accurate	Yes	No
2	**Construction Checklist**		
A	**Hanging**		
1	Unit is supported as required by manufacturer and specifications	Yes	No
2	Metal to metal connections eliminated to prevent noise problems	Yes	No
3	Adequate clearance around control panel for maintenance	Yes	No
4	Clear access below unit for easy maintenance	Yes	No
5	Unit labeled and is easy to see	Yes	No
6	Box openings temporarily sealed to maintain system cleanliness	Yes	No
B	**Ductwork**		
1	Balancing damper present on inlet duct	Yes	No
2	Sufficient length of straight ductwork installed upstream of unit	Yes	No
3	Downstream ductwork free of transitions for sufficient length	Yes	No
4	All components are accessible for maintenance	Yes	No
5	Flexible connector (vibration isolator) installed on inlet duct to avoid noise problems from metal to metal contact	Yes	No
6	Flex duct (if used) is installed in a way that avoids forming kinks on both inlet and outlet ductwork	Yes	No
C	**Electric Heating Coil**		
1	Heating coil inspected for damage prior to applying power	Yes	No
2	Wiring is properly sized	Yes	No
3	All electrical connections are properly grounded	Yes	No
4	All electrical connections are tight	Yes	No
D	**Electrical**		
1	Local disconnect switch installed in an accessible location	Yes	No
2	Motor rotation is in the proper direction	Yes	No
3	All electrical connections are tight	Yes	No
4	All electrical components are grounded	Yes	No
5	Variable speed selector is operational	Yes	No
6	P.E. switch is operational	Yes	No
E	**Controls - Installation**		
1	Temperature sensor calibration verified	Yes	No
2	Airflow sensor calibration verified	Yes	No
3	Point-to-point connections of control wiring verified	Yes	No
4	Central system accurately represents conditions of unit	Yes	No
F	**Controls - Startup**		
1	Cooling/heating sequence of control verified	Yes	No
2	Warm-up/cool-down sequence of control verified	Yes	No
3	Unoccupied sequence of control verified	Yes	No
G	**TAB**		
1	Motor rotation is in the proper direction	Yes	No
2	Motor overloads verified	Yes	No
3	Motor voltage and amps verified - each phase	Yes	No
4	Minimum airflow (cfm) (design/measured)	/	/
5	Maximum airflow (cfm) (design/measured)	/	/
6	Entering and leaving coil air temperatures (°F)	/	/

'No' Responses

Item	**Date**	**Reason for 'No' Response**

25. Operations and Maintenance: Energy Efficiency Checklist
(A copy is to be completed on the 18th of each month beginning in July 2006 through June 2007, the end of the initial commissioning process implementation for this building)
ASHRAE - Guideline 1-200X Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "Yes" and "No" responses at the bottom of the checklist, as applicable.

Name of Person who completed this checklist		**Month**	**Date Completed**	
Name:				
Item	**Task Description**		**Response**	
1	**Owner's Project Requirements**			
A	**Energy Efficiency Goal: Less than 20,000 kWh/month, 35 kW, and 120 therms**	Record Actual Usage	Was OPR Achieved	
1	Actual kWh		Yes	No
2	Actual kW		Yes	No
3	Actual therms		Yes	No
B	**Systems Manual and Building Documentation**	Provide any appropriate documentation	**Does the system operations meet OPR?**	
1	Have changes been made to the energy control hardware this month?		Yes	No
2	Have software changes been made, such as schedule or sequences?		Yes	No
3	Has the Systems Manual been updated?		Yes	No
4	Have changes been made to the drawings and schedules?		Yes	No
5	Has the commissioning team or commissioning authority been involved?		Yes	No
6	Has the optimization in section 24 of the Systems Manual implemented this month?		Yes	No
C	**General Owner's Needs**			
1	Are there any unresolved punchlist items related to energy efficiency open? If so list the numbers.		Yes	No
2	Was Elementary Control Services required to resolve any energy efficiency related issues this month?		Yes	No
3	Where the seasonal control checks in Section 88 of the Systems Manual implemented?		Yes	No
4	Are there any conflicts with users' needs and energy efficiency?		Yes	No
5	Was a commissioning optimization workshop held this month?		Yes	No

'Yes' and 'No' Responses

Item	**Date**	**Explain all Yes Responses and Reason for 'No' Response**

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

INFORMATIVE ANNEX N
QUALITY-BASED SAMPLING EXAMPLES

This annex provides information and examples on how to implement sampling to verify the HVAC&R requirements that are part of Guideline 0-2005 and this guideline. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process for HVAC&R System should carefully follow Guideline 0-2005, Guideline 1-200X, and other applicable commissioning technical guidelines tailored to their specific projects. An example is NIBS Guideline 3-2006, Exterior Envelope Technical Requirements for the Commissioning Process.

Introduction
There are three primary areas relating to HVAC&R systems where quality-based sampling is utilized for the on-going verification of achieving the OPR. These are:

- submittal reviews,
- site visits
- final commissioning process testing.

Submittal Reviews
The role of the Commissioning Authority and the commissioning team in the review of submittals is for on-going verification that the OPR is being achieved; it is not to relieve the design professional of his or her responsibility that the submittals meet the contract document requirements. Therefore, the Commissioning Authority accomplishes a two-part review of submittals – one to evaluate the contractor's submittal development process to verify OPR achievement and one to evaluate the design professional's submittal review process to verify OPR achievement.

These reviews are accomplished utilizing a random sampling approach of the HVAC&R submittals. Random (quality-based) sampling is utilized because it is the proven way to accomplish effective unbiased evaluations of materials against given criteria. The random sampling approach for a specific submittal varies based upon the number of attributes and components (e.g., chiller, pump, terminal unit, etc.) contained in the submittal and upon the importance to the OPR. There are two random sampling approaches that can be used. These include randomly sampling the attributes and components (when there are multiple attributes and components to sample from) and randomly sampling the pages of a submittal (when there is only one or few of the component type and several pages). In addition, the commissioning authority may select submittals to review from a random sample of all submittals, especially on projects with a large number of submittals.

The process to be followed by the Commissioning Authority in evaluating the contractor's submittal creation procedures is:

1. Review OPR
2. Review Construction Documents and BoD

3. Identify Key Criteria
4. Determine Sampling Rate
5. Accomplish Review
6. Document Results (provide timely comments to the design team)

The first three steps in the submittal review process should be accomplished prior to receiving submittals, since this will significantly reduce the turn-around time for submittal reviews by the Commissioning Authority.

Review OPR

The Commissioning Authority should review the current OPR to ensure understanding of the project success criteria. Specific attention should be given to those criteria that could be adversely impacted by the HVAC&R equipment performance, the system performance (includes parameters such as comfort, energy efficiency), and the ease of operation and maintenance in the submittals being reviewed.

Review Construction Documents and BoD

There is typically significant OPR information in the project specifications, plans, and the BoD for HVAC&R equipment, assemblies and systems. Therefore, it is important to review the appropriate specification section(s) and plans prior to reviewing the submittal, with particular attention given to those items that could adversely impact achievement of the OPR.

Identify Key Criteria

From the OPR and construction document reviews, the key criteria that will be used in reviewing the submittal should be identified and defined.

Determine Sampling Rate

The actual sampling rate to be utilized is based upon multiple factors. For HVAC&R components, in addition to specific requirements listed in the OPR, BoD, and construction documents, the impact on energy efficiency, maintenance, operability, comfort, indoor air quality, life of the component, and the relationship to other systems are criteria for evaluating the submittals. There may also be key code and standards issues; refrigerant safety and pressure ratings are two typical HVAC&R criteria for the commissioning authority to consider. All the criteria for evaluation of submittals can be developed and listed in table format to be randomly sampled for evaluation.

Factor	**Guidance**	**Sample Rate (% of components or % of pages)**
Complexity	Components of greater complexity typically require additional maintenance space and access points, as well as have a greater likelihood of involving multiple OPR criteria. Therefore, with greater complexity, the rate of sampling typically increases.	5-10% for low complexity 10-20% for medium complexity 20-40% for high complexity
Criticality	As the criticality of a component increases, relative to achieving the OPR, the sampling rate increases	5-10% for low criticality

	to provide a higher level of assurance that the OPR will be achieved. For example, in a data processing center where any downtime results in the loss of significant revenue, there is an obvious need for increased review compared to a retail clothing store. Another example of increased criticality would be where human life is at risk, such as in high containment biological laboratories.	100%-600% for high criticality (see Note 1)
Length	A submittal that has very little information (length) will typically result in a high sampling rate, whereas one with hundreds of pages will typically result in a low sampling rate of the submittal document. For non-critical components a random subset of the evaluation criteria may be used.	100% for less than 3 pages 75% to 100% for 4 to 10 pages 25% to 75% for 11 to 100 pages 5-25% for greater than 100 pages
Owner Input	The owner's understanding of quality-based sampling and level of assurance desired will typically have the greatest influence on the sampling rates utilized (see Note 2).	5-100% or greater
CxA	The Commissioning Authority's understanding of quality-based sampling and the Commissioning Process impacts the sampling rate (see Note 3).	5-100% or greater

Note 1: For sampling rates greater than 100% (e.g., extremely critical laboratory equipment that results in loss of life if fails), the approach is that two independent reviewers accomplish their evaluation following documented procedures. Therefore, if a 400% review is warranted, then there would be four independent reviews. Even when 100% sampling of a submittal is required, random sampling and verification of the component attributes should be a part of the process.

Note 2: It is important to understand that even if the sampling rate is 100% or greater, the approach to be taken is still one of random sampling. For example, for a submittal that has 100 air valves in a laboratory project, the review would use a random approach of first checking AV-1, 5, 10, 15…, then AV-2,6,11,16, etc. This random approach enables an unbiased evaluation of the submittal relative to the OPR. If issues are identified early in the review process (e.g., after a 20% review systemic issues have been identified), then there is no reason to accomplish the other 80% of the review as it has been shown that the submittal does not achieve the OPR and needs to be redone.

Note 3: It has been shown for inspection in manufacturing that those who do 100% inspections do not obtain as accurate an evaluation of the actual quality as those who practice scientific statistical random inspections for quality and meeting product needs. Although data and evaluation of construction has not been fully confirmed, the use of random samples in concrete and other construction products has been successfully verified using random samples. This is due to the fact that there is only a given amount of resources available to accomplish review during the design, construction, and operation phases of the project. For a given hour, the quality-based sampling approach allows for a more thorough in-depth review of a portion of the submittal against the OPR, whereas the 100% review is more of an overview trying to find errors. Because the purpose of the commissioning process is to evaluate OPR achievement (both positives and negatives), the quality-based sampling approach enables a fairer evaluation and improved results. For further information on sampling, refer to the references listed in section 9 of Guideline 0-2005

Accomplish Review
With the evaluation criteria and sample rate established, the submittal review is accomplished. Since the sample rate directly impacts the level of effort required by the Commissioning Authority, the sample rate needs to be determined during scope negotiation between the owner and Commissioning Authority. During these negotiations, it is important to remember that it is the contractor's duty to create 100% of the required submittals and it is the design professional's duty to review 100% of the submittals. It is the Commissioning Authorities role to evaluate the contractor's and design professional's work relative to OPR achievement. It is important to a successful commissioning process to keep complete records of the review findings for both items that meet the criteria (especially OPR) and items where the deficiencies are noted throughout the whole review process.

Document Results
The recommended approach to documenting the results of the Commissioning Authority's review is as follows:

1. Clearly state what was observed during the review.
2. Clearly state which OPR criteria was violated in the submittal.
3. Clearly state your recommendation for achieving compliance with the OPR.

Each comment needs to have space for the design professional to reply to the Commissioning Authority on the disposition of the comment.

The process to be followed by the Commissioning Authority in evaluating the design professional's submittal review procedures is as follows:

1. Review Responses to CxA Input
2. Identify OPR Concerns
3. Document Results

Review Responses to CxA Input
For each comment, the Commissioning Authority reviews the reply from the design professional. For those comments where the design professional incorporated the Commissioning Authority's input, follow-up with additional contractor submittals or as required.

Identify OPR Concerns
For those comments where the design professional did not incorporate the Commissioning Authority's input, review the potential adverse impact on achievement of the OPR.

Document Results
Document any adverse impacts on achieving the OPR and work with the design professional and owner in resolving the issue– either by changing the OPR to

match the new conditions or by getting the design professional to incorporate comments into submittal review response. This should be accomplished in a timely manner to avoid disruption of the construction process.

Site Visits
The contractor is responsible for installing and starting up 100% of the HVAC&R system, the design professional is responsible for verifying adherence to the project specifications, and it is the Commissioning Authority's responsibility to accomplish on-going verification that the contractor's work achieves the OPR. This is best accomplished through quality-based sampling of the completed HVAC&R Construction Checklists.

The intent of quality-based sampling of the Construction Checklist is that the Commissioning Authority reviews the completed HVAC&R Construction Checklists for accuracy, completeness, and any negative responses that require follow-up and resolution as each section is completed (e.g., 1, 2A, 2B, 3A, 3B, 3C…) for a component. This is based upon the contractor completing all checklists and upon the fact that sampling a random quantity will verify the quality of the contractor's action.

The Construction Checklists verify components from delivery through start-up. An individual component may be seen by the Commissioning Authority several times throughout its installation. Quality-based sampling allows for unbiased evaluation of OPR achievement at anytime during construction.

The sampling rate to be utilized during a particular site visit varies depending upon the factors in the table below. The table provides general guidance for HVAC&R components. This may not apply to assemblies and systems that support the HVAC&R systems, if they are not part of the commissioning process scope. For example, if the envelope is not included in the scope of the commissioning process for a specific building, there will not be any checklists for the envelope components and this will be included in the site visits as an item to be checked to evaluate the quality of the envelope as it impacts the performance of the HVAC&R systems.

Factor	**Guidance**	**Sample Rate (% of components or % of pages)**
First Completed Construction Checklist	It is recommended that for the first Construction Checklist to be completed by the contractor for a particular component type, it should be verified and reviewed with the contractor to improve their understanding of the importance of completing all checklists as the work progresses and to eliminate systemic issues before they become problems. This is required, even though it will be included in the pre-construction commissioning process session.	100%
Pace of Construction	When the pace of construction is slow and there have been few Construction Checklists completed since the previous site visit, the sampling rate increases. When the pace is fast and many checklists have been completed, the sampling rate	40-60% for slow pace 5-20% for fast pace

	decreases.	
Number of Components	If there is only one instance of a component, the rate of sampling is typically 100%, and where there are many similar components the sampling rate decreases.	100% for a single component 5-15% for many components

Final Commissioning Process Testing

The sampling rate for the final commissioning process tests to verify OPR achievement is based upon the following:

Factor	**Guidance**	**Sample Rate**
Complexity	The greater the complexity of HVAC&R system and interaction of OPR between multiple components, typically the more additional evaluation and testing is required to verify OPR achievement. Therefore, with greater complexity, the rate of sampling typically increases.	10-20% for low complexity 20-40% for medium complexity 40-80% for high complexity
Criticality	As the criticality of component increases, relative to achieving the OPR, the sampling rate increases to provide a higher level of assurance that the OPR will be achieved. For example, a data processing center where any downtime results in the loss of significant revenue, there is an obvious need for increased testing compared to a retail clothing store. Another example of increased criticality would be where human life is at risk, such as high containment biological laboratories.	10-20% for low criticality 100%-600% for high criticality (see Note 1)
Owner Input	The owner's understanding of quality-based sampling and level of assurance desired will typically have the greatest influence on the sampling rates utilized (see Note 2).	5-100% or greater
CxA	The Commissioning Authority's understanding of quality-based sampling and the Commissioning Process impacts the sampling rate (see Note 3).	5-100% or greater

Note 1: For sampling rates greater than 100% (e.g., extremely critical laboratory equipment that results in loss of life if it fails), the approach is that two independent testers using different instrumentation accomplish their evaluation following the documented test procedures. Therefore, if a 400% review is warranted, then there would be four independent testers.

Note 2: It is important to understand that even if the sampling rate is 100% or greater, the approach to be taken is still one of random sampling. For example, for a facility that has 40 rooms, the test to verify the comfort OPR would use a random approach of first checking rooms 100, 105, 110, 115…, then rooms 101, 106, 111, 116, etc. This random approach enables an unbiased evaluation of the comfort throughout the facility relative to the OPR. If issues are identified early in the testing process (e.g., after a 20% testing systemic issues have been identified), then there is no reason to accomplish the other 80% of the testing as it has been shown that the system does not achieve the OPR and something needs to be changed.

Note 3: Because the final commissioning process tests to verify OPR achievement should focus on specific OPR criteria, the skills of the Commissioning Authority in developing appropriate, tailored tests will greatly impact the sampling rate required to determine OPR achievement. Typically, a Commissioning Authority that creates facility and system based tests will have lower sampling rates than one that creates component tests.

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

INFORMATIVE ANNEX O

SYSTEMS MANUAL

This annex provides an example of how to implement part of Guideline 1-200X. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X, and other applicable commissioning technical guidelines tailored to their specific projects. An example is NIBS Guideline 3-2006, Exterior Envelope Technical Requirements for the Commissioning Process.

This example Commissioning Plan is for a fictitious New ASHRAE Headquarters, based upon information from other commissioning process projects. It is not related to any actual project.

See ASHRAE Guideline 0-2005 for description of Systems Manual requirements. The size and complexity of the facility will determine how many binders are required. Some owners may also want the information digitized and presented in CD format for long-life storage on a permanent hard drive or other long life media.

The following is an example of a systems manual format and content.

SYSTEMS MANUAL

ASHRAE HEADQUARTERS FACILITY

HVAC&R SYSTEMS

TAB	Systems Manual Contents
A.	Executive Summary
B.	Owners Project Requirements
C.	Basis of Design Information
D.	Contractor Listing and Emergency Information
E.	Construction Record Documents
F.	Equipment Information by Specification Division and Section number
a.	Final Specifications
b.	Approved Submittals
G.	Systems Operating Procedures and Limitations
H.	Maintenance Procedures and Schedules
I.	Operational Record Keeping
J.	Benchmarking and Optimization
K.	Operations and Maintenance Manuals
L.	Training Information and Records.
M.	Commissioning and Testing Results

A. Executive Summary

This manual contains an overview of the building mechanical system requirements, basis of design, relevant construction documents and specifications, approved submittals, operating criteria, operational record keeping procedures, maintenance procedures and schedules, benchmarking and optimization, operation and maintenance manuals, and training records. The information is intended to provide the information to operate and maintain the building mechanical system in conformance to the owner's project requirements.

Changes to the manuals are expected as the building maintenance systems are developed and changes to the system occur.

Mechanical systems in this facility include: *air cooled chillers, chilled water pump, air handlers, exhaust fans, interior variable air volume terminals, exterior zone fan terminals with parallel fans and electric heat*. See as-built drawings in central maintenance office for specific arrangements and locations.

Design of these systems was provided by:

Name/Agency	Address	Phone #	email
Architect			
Mechanical Engineer			
Electrical Engineer			

Systems were supplied and constructed by:

Name/Agency	Address	Phone #	email
Mechanical Contractor			
Chiller Mfg.			
AHU Mfg.			
Pump Mfg:			
Terminal Box Mfg.			

B. Owner's Project Requirements

Insert final copy for mechanical systems

C. Basis of Design

Insert final copy for mechanical system

D. Contractor Listing and Emergency Information

Insert a listing of all contractors including address, phone, and email. Include emergency information on building shut down and other critical operations.

E. Construction Record Documents

Insert final mechanical specifications and describe locations of as built drawings

F. Equipment Information by Specification Division and Section number Approved Submittals

(Place specification, approved submittal and O&M data in the same tab)

a. Specifications
Insert final copy for mechanical system indexed by specification section number

b. Approved Submittal
Insert final copy of specific submittal

c. O&M data
Insert manufacturer provided O&M manuals that have been verified and localized to the installed building equipment.

d. Warranties
Insert System and Equipment warranties arranged by specification section sequence.

G. System Operating Procedures and Limitations

Sequence of operation:
Insert copy of final approved sequence of operation

System operation setpoints:

Unit	Temperature	Summer Setback – Unoccupied	Winter Setback – Unoccupied	
Occupied Rooms	73 °F +/- 2 °F	85 °F	60 °F	
Chilled Water	55 °F			

System Schedules

Unit	Mon-Fri	Saturday		
Occupied Rooms	0600 - 1800	0600 - 1200		
Lobby	0600 - 1800	0600 - 1200		

Emergency Operation:

Fire Alarm Condition: *Describe system function and shutdown during fire alarm activation.*

Smoke Exhaust: *Describe system operation during smoke exhaust operation, e.g. fan activation, damper operation, etc.*

Extreme Temperatures: *Describe system operation variations during extreme temperature conditions, if any.*

H Maintenance Procedures and Schedules:

Procedures: *Insert any special-condition procedures, e.g., dust or vegetation removal from chillers, etc.*

Schedules: *Insert schedule for maintenance of each item of mechanical equipment.*

I Operational Record Keeping:

Equipment Logs: *Describe inspections and testing required on a routine basis and standard forms required, e.g. chiller temperature and electrical conditions, cooling tower water tests, etc.*

Include sample blank forms if available.

Trend Logs *Describe computer generated trend logs for system and space conditions, e.g., sample space temperature and humidity conditions, chilled water temperatures, CO_2 levels, KWHs, etc.*

J Benchmarking and Optimization

Benchmarking *Insert listing of owners project requirements for specific systems and method or form for periodic comparison. Measurement and verification procedures are inserted here.*

Optimization *Insert plans and programs for improving system performance.*

K. Operations and Maintenance Manuals

a. O & M data

Insert manufacturer provided O&M manuals that have been verified and localized to the installed building equipment, arranged by specification section sequence.

b. Warranties

Insert system equipment warranties arranged by specification section sequence.

L Training Records - Arrange in tabs by specification numbers.

Training Plans	*Insert training plans used for each type of equipment along with session syllabus used.*
Training Materials	*Insert training materials used arranged in specification sequence. Describe location or sources of available additional training*
Training Records	*Insert records of training, schedules, sign in sheets, etc.*

M. Commissioning Records *Insert the final commissioning plan and completed commissioning report with verification and testing forms and records for each building system arranged according to specification sequence.*

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

INFORMATIVE ANNEX P
TRAINING MANUAL AND TRAINING NEEDS

This annex provides information on training requirements for HVAC&R systems and assemblies. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X and other applicable commissioning technical guidelines tailored to their specific projects.

Pre-Design Phase

Training Requirements and Implementation begin at project conception and are part of the Owners Project Requirements (OPR). At the implementation stage the owner needs to address the source of operating personnel, in-house or out sourced labor and services, and the level of responsibility assigned to the Facilities/Project Manager for the site. OPR requirements for extended warranty and service agreements with the contractor or OEM (original equipment manufacturer) need to be addressed at the time of project inception.

In the implementation stage, beginning with assigned individual roles and responsibilities, the OPR for training are considered in a manner similar to choosing any of the varied systems, components, and assemblies that establish the level of quality and performance expectations expressed by the Owner in the OPR.

The criteria used to determine the minimum level of acceptance required by the Training OPR will guide the development and coordination of the training of personnel who are assigned responsibilities of maintaining the HVAC&R systems performance in the OPR. This includes energy, fire and safety, indoor environment and occupant comfort requirements that related to the HVAC&R systems. During the Pre-Design Phase, the initial training agenda needs to be developed to a level that reflects the Training required to meet the OPR. This provides the initial guidance to the design team. It includes;

- Establish development requirements for the Training Plan
- Identify Essential Components or Systems requiring formal training and the estimated time designated for training by hours (unit cost).
- Determine Skill level requirements for Operating Staff meeting the OPR levels of performance
- Create Checklist of training requirements necessary to maintain warranty conditions and service life
- Specify Requirements for acceptable organization and implementation of the OEM training requirements prior to Occupancy
- Clearly identify the training requirements of Contractor’s work force for the equipment maintaining the interior environment during the Construction Phase.
- Develop Training methods that meet the OPR, including incorporating OEM training with service bulletins, recalls, and implantation of changes in operating procedures as facility systems and components age and degrade in performance levels.

- Provide clear understanding of the OPR for training material, training sessions (schedule), and trained personnel necessary, prior to and after occupancy by the owner.

Training responsibilities and the position or person assigned these responsibilities must be clearly defined in the OPR and reviewed before moving into the Design Phase. This is of extreme importance when essential equipment or systems are provided by the Owner.

The HVAC and refrigeration design needs to satisfy the operating personnel for the following OPR topic areas, including consideration of training required to continuously achieve the benefits of designs that optimize each requirement.

- Reparability
- Interchangeability
- Accessibility
- Replaceability
- Maintainability
- Extendability
- Adaptability
- Lifecycle Replacement Sequence
- Cost Analysis of Component Servicing and Maintenance cycles
- Complexity of the OEM and Systems in day to day operation.

Controls at the system and component level are essential for all HVAC&R systems and assemblies. There must be special effort directed at the training requirements as the design develops, versus considering the training afterward as a result of the controls design.

Beyond mechanical maintenance the skill set required at each level of the operating hierarchy for Direct Digital Control Systems (DDC) needs to be defined in the OPR. These DDC systems have various levels of control, hierarchy; some levels require computer programming skills that are beyond the means of an owner to support. At a minimum the OPR should define the responsibilities and training necessary for in-house and out-sourced contractors (service plan) of site DDC Systems. The level of interoperability and any additions to interoperability not currently used at the site or organization requires additional training for the systems to be successful. Issues addressed in the OPR should include the following:

- DDC in-house engineering, operations, and maintenance (EOM) requirements
- DDC service plans and warranty requirements
- Procedures for maintaining record documents and service records of DDC Systems
- Training and Certifications requirements for in-house and service contractor personnel
- Written training matrix updated to each level in the DDC Hierarchy.

Design Phase

During the Design Phase, the DESIGN PROFESSIONAL following the OPR will define the training requirements and implementation schedule for the project in the contract documents. Sometimes this may require specific needs for each installing contractor, and for in-house maintenance, and out-sourced service personnel. The performance of these training services is verified both as part of the submittal review process and as the training sessions occur. There will be additional training requirements that continue to evolve during the design and construction phases of the project. It is recommended to have “Needs Development Workshops or Sessions” during design and construction. These need to be defined in the specifications. Special note should be given to the training and service requirements of equipment and systems not provided by the project Contractor. This is usually owner provided equipment or systems that occur outside the project submittal review. In some cases there may be two or more construction projects, with separate contractors or in-house construction. This requires coordination of training needs to prevent duplication and acceptable scheduling of trainers and trainees.

Procedure training on spare parts availability and service response times should be clearly defined by the DESIGN PROFESSIONAL and verified in the submittal process.

During the design phase the DESIGN PROFESSIONAL should clearly define all special requirements for storage of equipment or systems prior to installation. Training necessary to maintain the equipment prior to Owner acceptance is identified and monitored by proper application of the Contractors QA/QC program. Special training of Contractor personnel handling equipment with special requirements should be monitored by the CxA demonstrating training and competence meeting the OPR during all periods that the HVAC&R equipment and systems are operated during construction and warranty. Equipment must be maintained to prevent any degradation prior to turnover to the owner for operations.

Contractor Special Training, Licensing, Certification (Construction Phase)

After the notice to proceed, the Contractor is required to provide initial submittals in the stated period of time. One of the initial submittals usually required is the Contractors QA/QC Program. This Program outlines the methods used by the Contractor to assure his personnel have the proper Training, Licensing, and Certifications to perform tasks assigned. In addition, the criteria necessary to maintaining the project specific OPR identified in the Contractor QA/QC Program. On a frequent basis the CxA should verify and note compliance by the Contractor to required Training, Licensing, and Certification requirements or activities and other quality checks identified in the Contractors QA/QC program or required by the contract.

Certification Training for procedures in the use of unique equipment or assemblies should be required at locations other than the actual job site. In such cases the DESIGN PROFESSIONAL may require verification of current and up-to-date certification and valid accreditation documents for the organization or individual issuing the certification. The role of the CxA in verification of proper training for certification is to randomly check the documentation necessary to demonstrate compliance with the OPR. The requirement for assuring that the proper documentation is valid remains with either the design team or owner’s project or construction manager.

Construction Phase Training

There should be an initial training session during the construction period and prior to contractor training for the owner's EOM and users by the design team on the OPR and Basis of Design, including system limitations. This is especially required for all HVAC&R systems that are critical to the success of the facility.

The CxA should hold a training development workshop with the EOM (including any service contractors) several months before the final training sessions are scheduled and the scope of training-sessions content is set. This workshop is for gathering information from the EOM (engineering, operations, and maintenance) staff to determine the actual training requirements based upon the approved equipment, assemblies, and systems for the building, upon a walk-through of the building, and upon the review of final plans and specifications. This may require an increase or decrease in actual training requirements than the requirement included in the contract documents. This is frequently related to the final equipment, components, and HVAC&R systems selected by the owner, design team, and contractor.

Systems Manuals need to be complete before owner's personnel are provided training and used in the training sessions.

Training on the use of the Systems Manuals should be a combined training effort of the design team, the CxP team, and the contractor.

The CxA should review the contractor's schedule all HVAC&R related training. Resources and time for HVAC&R training can place great demand on both the contractor and the EOM and service firm personnel at the end of the Construction Period. HVAC&R systems are especially impacted both because of a high level of training required and the HVAC&R systems are some of the last systems installed in the construction process. Early training must be scheduled for project success. The CxA must document that training and the required level of competence learned in the training meets the OPR.

The Contractor is responsible for the:

- Start-up
- Testing
- Adjusting
- Balancing
- Systems Manual
- Training

for all systems and equipment prior to the functional testing or measurement and verification of these systems and equipment. The Cx Team must verify through assembled documentation that the Contractor Personnel are trained and competent to perform these activities.

The contractor must begin early training on any major changes in the automated preventive maintenance and service program that is included by systems installed and required by the contract.

Testing and Verification demonstrating compliance of systems and equipment to the OPR should be witnessed by the Owner's O&M staff as part of Contractor's Training Plan. The CxA facilitates the monitoring of functional and commissioning tests by designated Owner personnel performed as part of the GC's acceptance plan. The benefit to the Owner in monitoring these tests are lessons learned and corrective review of O&M procedures prior to Substantial Completion and operation of the systems by the Owner. Using the information developed in this start-up phase, the Owner and the CxA should evaluate the abilities of in-house personnel to perform the O&M necessary for successful operation of various systems and to prevent future warranty issues. A value analysis of OEM service programs and maintenance by the CxA during this period is useful information for the Owner's consideration. Documentation gathered by the CxA during this monitoring phase is useful to the training program and in the acceptance phase.

The majority of HVAC&R systems and assemblies training should occur in the construction phase, prior to Substantial Completion. The initial training is developed at a level to assure that the Owner's O&M personnel are competent in the proper operation of the systems and equipment during occupancy. The training prior to Final Acceptance takes place after the facility has been occupied during the warranty period between Substantial Completion and Final Acceptance. This allows for training in seasonal operation and site specific issues to be addressed in the training program. Using a two step training program, the CxA will facilitate the coordination of site specific issues:

- Warranty/Guaranty
- Service Call-up or Call-back
- Systems and Equipment Performance
- Seasonal Transition of Equipment
- Spare Parts Inventory
- Equipment or Systems Service Bulletins
- Life-cycle analysis
- Modified Preventative and Predictive Maintenance Procedures

Construction Phase Close Out:

As systems are completed the Contractor may be required to or may elect to use these systems to maintain an environment at the worksite meeting specified requirements in executing the construction process. Prior to turnover, these systems operated by the Contractor need to be validated for proper O&M by Contractor Personnel. The validation of operating equipment at turnover must include documentation that the Contractor Personnel were properly trained in both operation and maintenance of the system and that the equipment maintenance schedule was maintained during the period of contractor operation. Lessons learned and information gathered on the operations of the systems during start-up and operations are valuable to the owner and must be included in the turnover training of the Owner's Operating Staff and coordinated by the CxA before the Owner assumes these responsibilities.

Occupancy Phase:

At Substantial Completion and Owner Operations and Occupancy the major training responsibilities becomes the responsibility of the Owner. Specifically, it will become the responsibility of the Owner's Facility Chief Engineer and Building Manager. The CxA will coordinate this shift in responsibilities until Final Acceptance or beyond as required by the Owner's On-going and Continuous Commissioning Process activities. The CxA/Chief Engineer/Building Manager relationship in this phase will coordinate the training requirements to implement and optimize the performance of:

- Existing Service and Outsourcing of Service Plans and Programs
- Organization and Training of O&M staff and
- Qualification of Training Requirements of staff positions
- Warranty/Guaranty implementation and enforcement
- Service Call-up or Call-back tracking and evaluation
- Systems and Equipment Performance in:
  - Measurement
  - Verification
  - Analysis (Benchmarking and Life-cycle)
  - Optimization
  - Re-commissioning Cycle
  - Optimization
- Seasonal Transition of Equipment and tracking impact of weather cycles and systems performance
- Spare Parts Inventory and response times for service
- Equipment or Systems Service Bulletins and training updating
- Life-cycle and Maintenance Budget Planning
- Modification of Preventative and Predictive Maintenance Procedures to meet site specific conditions.

The Facility/Building Manager will assess the benefits and costs of maintaining a Training Cycle that represents the interests of the Owner. The CxA can be of great benefit to the Building Manager in the initial organization of construction documents providing a method to keep training up-to-date with the cycle of changes in equipment and use of the building throughout the lifecycle.

Summary:

The processes of training and systems optimization will remain a responsibility of the Chief Engineer and Facility/Building Manager for the life of the Facility. To assure the continuing need for training and understanding of systems and O&M, a paper-trail of the learning process is essential to the continuing success of site operations. The CxA is an essential part in getting this process off the ground, and with continuing commissioning efforts, provides the guidelines to optimize the training process through the life of the building. The documentation of the training process coordinates the:

- Coordination and Organization of Responsibilities for assigned to a position
- Verification of understanding and competence in what was learned in training and O&M
- Proper application of Preventative and Predictive Maintenance of Systems
- Organization of application of Service Bulletins and OEM call-backs
- Clear application of system performance and degradation information
- Optimal benefits from lessons learned
- Coordination of Personnel Changes and Mentoring for a position.

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

INFORMATIVE ANNEX Q

PUBLICATIONS, ARTICLES, REFERENCES, CODES, REGULATIONS, AND STANDARDS

This annex provides example of references that can be useful to the commissioning practitioners applying the Commissioning Process.

This annex provides a listing of reference documents that can be utilized by the commissioning team in their implementation of the commissioning process from project conception through occupancy and operations. The references have been separated into the following categories as they relate to the project's development.

- Preparing for the Commissioning Process
- Pre-Design Phase
- Design Phase
- Construction Phase
- Occupancy and Operations Phase

ASHRAE references include a brief description of their contents and how they apply to the associated phase of the project development.

Non-ASHRAE references are provided (without comment) as additional available sources that may provide useful data, information and insight when applying the commissioning process to a projects development and turnover to the Owner.

Inclusion of a reference in this Annex does not mean that it follows Guideline 0-2005 or Guideline 1-2006. The references contain material that may be of use to the commissioning team. However, the referenced material must be understood and modified to fit the needs of the specific project and to match that of the commissioning process detailed in Guideline 0-2005. Inclusion of a reference also does not imply endorsement by ASHRAE or by the Guideline Project Committee. Use references with caution and only after full understanding of the commissioning process.

Preparing for the Commissioning Process

<u>ASHRAE Publications:</u>

14. ASHRAE Guideline 0–2005 "The Commissioning Process"
    - This guideline presents details on the Commissioning Process without focusing upon specific systems or assemblies. Guideline 0 details what is required for a high-quality and effective Systems Manual and how and when it is developed. Guideline 0 is a guide for preparation of Guideline 1, which is intended to provide specific and detailed information on how to implement the Commissioning Process for HVAC&R systems and assemblies.

15. ASHRAE Guideline 5–1994 " Commissioning Smoke Management Systems"
    - This guideline provides methods for verifying and documenting that the performance of smoke management systems conforms to design intent. This guideline was written prior to Guideline 0-2005 and does not utilize consistent terminology or approach to the commissioning process.

16. ASHRAE Guideline 8-1994 "Energy Cost Allocation for Multiple Occupancy Residential Buildings"

- This guideline recommends methods, applications, and terminology for energy cost allocation systems in multiple-occupancy residential buildings and may be beneficial in the preparation of a commissioning process for this type of project.

17. ASHRAE Guideline 12-2000 "Minimizing the Risk of Legionellosis Associated with Building Water Systems"
    - This guideline provides information and guidance in order to minimize Legionella contamination in building water systems. This can be a valuable resource during the design phase of a project.

<u>Other Publications:</u>

U.S GSA and DOE "Building Commissioning Guide", Version 2.2, July 30, 1998

<u>Books:</u>

1. The Building Commissioning Handbook, Heinz and Casault, APPA and BCA, 2004
2. A Practical Guide for Commissioning Existing Buildings, ORNL/TM-1999/34, APRIL 1999
3. AABC Commissioning Guideline, AABC, 2002
4. NEBB 1999 "NEBB Procedural Standards for Building Systems Commissioning"

<u>Others</u>

1. Adopting the Commissioning Process for Successful Procurement of Schools, DGS, State of California, 2003

Pre-Design Phase

<u>ASHRAE Publications:</u>

1. ASHRAE Fundamentals Handbook – 2005
    - This is a solid resource for reviewing and understanding the basic principles and obtaining essential data for HVAC systems during the pre-design phase. Chapters, include:
        - Theoretical equations and information that provides the basis of how HVAC&R processes perform and developed.
        - General Engineering Data relating products and events that affect the performance of HVAC&R systems.
        - Basic Materials used in, or affect, the operation of HVAC&R systems.
        - Load and Energy Calculations used to select HVAC&R equipment, components and assemblies.
        - Ductwork and Piping design criteria, sizing and layout.
        - Data relating to controls, building envelopes, and physical properties of materials.

2. ASHRAE Refrigeration Handbook – 2006
    - This is a resource for reviewing and selecting refrigeration equipment and systems during the pre-design phase. This handbook material is used for applications other than human comfort including:
        - Basic refrigeration system practices, food transport and storage requirements and industrial applications, and details the latest technologies and techniques available in the field.
        - Thermal Properties of Foods, Codes and Standards, Commodity Storage Requirements, and Refrigerant-Control Devices

3. ASHRAE Guideline 14-2002 "Measurement of Energy and Demand Savings"
    - Provides guidelines for reliably measuring energy and demand savings of commercial equipment. These measurements can be used to document energy savings for various credit programs, such as emission reduction credits associated with energy efficiency activities. A good reference to use during the pre-design phase when energy consumption considerations are paramount.

4. ASHRAE Standard 55–2004 "Thermal Environmental Conditions for Human Occupancy"

- This standard is essential as a reference during the pre-design phase of a project. It specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. The environmental factors addressed are temperature, thermal radiation, humidity, and air speed; the personal factors are those of activity and clothing.

5. ASHRAE Standard 62.1–2004 “Ventilation for Acceptable Indoor Air Quality”
   - This standard is essential as a reference during the pre-design phase of a commercial, institutional or industrial project. It specifies minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects. This standard is intended for regulatory application to new buildings, additions to existing buildings, and those changes to existing buildings that are identified in the body of the standard. This standard is intended to be used to guide the improvement of indoor air quality in existing buildings.

6. ASHRAE Standard 62.2–2004 “Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings”
   - This standard is essential as a reference during the pre-design phase of a residential project. It applies to spaces intended for human occupancy within single-family houses and multifamily structures of three stories or fewer above grade, including manufactured and modular houses. This standard does not apply to transient housing such as hotels, motels, nursing homes, dormitories, or jails.

<u>Books:</u>

1. Uniform Mechanical Code
2. International Building Code
3. International Mechanical Code
4. International Plumbing Code
5. ASHRAE GreenGuide
6. ASHRAE Terminology of HVAC&R
7. ASHRAE 2002 “Commissioning, Preventive Maintenance, and Troubleshooting Guide for Commercial Ground-Source Heat Pump Systems”
8. ASHRAE 1998 “Design, Construction, and Operation of Healthy Buildings: Selected Papers from Healthy Buildings/IAQ 97”
9. REHVA 2001 “Displacement Ventilation in Non-Industrial Premises”
10. CUBSE 1999 “Energy Assessment and Reporting Methodology”
11. Energy Institute Pre / Donald R. Wulfinghoff 2000 “Energy Efficiency Manual”
12. SMACNA 1997 “Energy Systems Analysis and Management Manual”
13. CIBSE 1999 “Environmental Factors Affecting Office Worker Performance”
14. The RJA Group 2001 “From Model Codes to the IBC: A Transitional Guide”
15. ASHRAE 2001 “Fuel Cells for Building Applications”
16. MIT Press/ Bruce D. Hunn 1996 “Fundamentals of Building Energy Dynamics”
17. AIA Press 1996 “Guidelines for Design and Construction of Hospital and Health Care Facilities”
18. AIA Press “1999 “Guidelines for Planning and Design of Biomedical Research Laboratory Facilities”
19. ASHRAE 2004 “HVAC Design Guide for Tall Commercial Buildings”
20. CIBSE 1999 “Minimizing Pollution at Air Intakes”
21. CIBSE 2000 “Minimizing the Risk of Legionnaires' Disease, TM13”
22. ASHRAE 2003 “Mold and Moisture Management in Buildings”
23. Cold Air Distribution Design Guide, EPRI TR-105604s, 1995
24. Cool Storage Total Building Construction Cost Benefits, An Owner’s and Architect’s Guide, EPRI TR-104521, 1995
25. Creating The Productive Workplace, Clements-Croome, E&FN Spon, 2006

Design Phase

<u>ASHRAE Publications:</u>

1. ASHRAE HVAC Applications Handbook – 2003
   - A resource for reviewing and understanding the application of HVAC equipment and systems during the design phase. This book provides background information to

designers new to the application as well as those needing a refresher on the topic. Sections include:

    - Comfort Applications
    - Industrial Applications
    - Energy-Related Applications
    - Building Operations and Management
    - General Applications including Justice Facilities (prisons, courthouses, etc.), Health Care Facilities, Laboratories, Sound and Vibration Control, Kitchen Ventilation, and Thermal Storage

2. ASHRAE HVAC Systems & Equipment Handbook – 2004
    - A resource for reviewing and understanding the characteristics and operation of specific HVAC equipment and systems during the design phase. Sections include:
        - Air-Conditioning and Heating Systems
        - Air-Handling Equipment
        - Heating Equipment
        - General Components
        - Unitary Equipment

3. ASHRAE Guideline 3-1996 "Reducing Emission of Halogenated Refrigeration and Air-Conditioning Equipment and Systems"
    - This guideline can be useful during the design phase to utilize and specify recommended practices and procedures covering emission reduction of halogenated hydrocarbon and halogenated ether refrigerants:
        - From stationary refrigeration, air-conditioning, and heat pump equipment and systems
        - During manufacture, installation, testing, operation, maintenance, and disposal of equipment and systems.

4. ASHRAE Guideline 13-2000 "Specifying Direct Digital Control Systems"
    - This guideline is a good resource when developing a DDC specification during the design phase. It provides recommendations for developing specifications for direct digital control (DDC) systems in heating, ventilating, and air-conditioning (HVAC) control applications.
    - This guideline is under continuous maintenance, which is a process ASHRAE uses to keep guidelines current through the issuance of addenda, or revisions.

5. ASHRAE Guideline 16-2003 "Selecting Outdoor, Return and Relief Dampers for Air-Side Economizer Systems"
    - This document provides the basis for selecting and sizing control dampers commonly found in constant air volume and variable air volume air-handling units and systems with airside economizers. The Guideline helps system designers make correct damper selection and sizing decisions, a critical first step in designing a control system.

6. ASHRAE Standard 26–1996 "Mechanical Refrigeration and Air-Conditioning Installations Aboard Ship"
    - This standard covers commonly used and appropriate practices for marine applications as well as the requirements of the U.S. Coast Guard, American Bureau of Ships, Lloyd's Register, and other marine societies are also included.

7. Standard 52.2-1999 -- Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size (ANSI approved)

    - This standard establishes a test procedure for evaluating the performance of air-cleaning devices as a function of particle size.

8. ASHRAE Standard 90.1–2004 "Energy Standard for Buildings Except Low-Rise Residential Buildings"
    - This is a must resource when designing commercial buildings. The purpose of this standard is to provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings.

9. ASHRAE Standard 90.1-2004 “User’s Manual” - for Guideline 90.1-2004
    - This User’s Manual provides detailed instruction for the design of commercial and high-rise residential buildings to ensure their compliance with ANSI/ASHRAE/IESNA Standard 90.1-2004.

10. ASHRAE Standard 90.2–2004 “Energy Efficient Design of Low-Rise Residential Buildings”
    - This is a must resource when designing residential buildings. The purpose of this standard is to provide minimum requirements for the energy-efficient design of residential buildings.

11. Standard 113-2005 – Method of Testing for Room Air Diffusion

    - Specifies equipment and procedures for measuring air speed and air temperature in occupied zones of building spaces.
    - Applies to furnished or unfurnished spaces with or without occupants
    - Applies to air distributions systems, including systems in which air outlets are located inside and outside, or outside of the occupied zone; and in which local air velocities in the occupied zones are or are not under control by individual occupants.

12. ASHRAE Standard 135-2004 “BACnet® - A Data Communication Protocol for Building Automation and Control Networks”
    - This standard can be useful when designing projects that will be use the BACnet protocol.
    - This standard is under continuous maintenance, which is a process ASHRAE uses to keep standards current through the issuance of addenda, or revisions.

13. ASHRAE Standard 154-2003 “Ventilation for Commercial Cooking Operations”
    - This standard can be useful when designing projects that will be include kitchen ventilation systems. The purpose of this Standard is to provide design criteria for the performance of commercial cooking ventilation systems.

14. ASHRAE Standard 169-2006 “Weather Data for Building Design Standards”
    - This standard provides a comprehensive source of climatic data for those involved in building design. It provides a variety of climatic information for use primarily in the design, planning, and sizing of building energy systems and equipment

<u>Books:</u>

1. ASHRAE/Harriman 1992 “Desiccant Cooling and Dehumidification”
2. ASHRAE 1994 “Design Guide for Cool Thermal Storage”
3. ASHRAE 2002 “Designer’s Guide to Ceiling-Based Air Diffusion”
4. Wiley/Michael Newman 1994 “Direct Digital Control of Building Systems”
5. Hacienda Blue Publishers/ F. Shadpour 2001 “Fundamentals of HVAC Direct Digital Control, The”
6. ASHRAE/ H. Sachs 2002 “Geology and Drilling Methods for Ground-Source Heat Pump Installations: An Introduction for Engineers”
7. ASHRAE 1997 “Ground-Source Heat Pumps - Design of Geothermal Systems for Commercial and Institutional Buildings”
8. ACEEE 2000 “Guide to Energy-Efficient Commercial Equipment”
9. NAIMA 1997 “Guide to Insulated Air Duct Systems, A”
10. ASHRAE 2003 “HVAC Design Manual for Hospitals and Clinics”
11. ASHRAE 2002 “Laboratory Design Guide”
12. NAFA 1996 “NAFA Guide to Air Filtration”
13. AABC 2002 “National Standards for Total System Balance”
14. CIBSE 2002 “Noise and Vibration Control – CIBSE Guide B5”
15. ASHRAE 1991 “Practical Guide to Noise and Vibration Control for HVAC Systems”
16. ASHRAE 2000 “Practical Guide to Seismic Restraint, A”
17. ASHRAE 2002 “Principles of Smoke Management”
18. NEBB 1996 “Procedural Standards for Certified Testing of Cleanrooms”
19. NEBB 1994 “Procedural Standards for the Measurement and Assessment of Sound and Vibration”
20. SMACNA 1998, 2nd Edition “Seismic Restraint Manual: Guidelines for Mechanical Systems”

21. ICC 2003 “Smoke Control Provisions of the 2000 IBC: An Interpretation and Applications Guide”
22. NEBB 1994 “Sound and Vibration Design and Analysis”
23. ASHRAE/*Qingyan Chen; Leon Glicksman 2003 “*System Performance Evaluation and Design Guidelines for Displacement Ventilation”
24. ASHRAE 2004 “Thermal Guidelines for Data Processing Environments”
25. ASHRAE 2003 “Underfloor Air Distribution Design Guide”
26. McGraw-Hill/ Steve Chen, Stanley Demster 1996 “Variable Air Volume Systems For Environmental Quality”

Construction Phase

<u>ASHRAE Publications:</u>

1. ASHRAE Standard 15-2004 “Safety Standard for Refrigeration Systems”
    - This standard can be used as a guide for safe design, construction, installation, and operation of refrigeration systems,

2. ASHRAE Standard 15-2001 “User’s Manual” - for Guideline 15
    - This user’s manual was developed as a companion document to ASHRAE Standard 15-2001. It does not reflect the addenda and changes incorporated into Standard 15-2004. The User’s Manual clarifies the intent of the Standard and provides an explanation of the rationale behind it. It eases use of the standard by including illustrations and examples of accepted industry practice, as well as explanations of and supporting references for formulas in the Standard.

3. ASHRAE Standard 111-1998 “Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and refrigeration Systems”
    - This standard is useful in establishing desired procedures to be performed and provided by the Testing, Adjusting and Balancing technicians. Use of this standard will:
        - Provide uniform and systematic procedures for making measurements in testing, adjusting, balancing and reporting the performance of building heating, ventilation, air-conditioning, and refrigeration systems in the field.
        - Provide means of evaluating the validity of collected data considering system effects.
        - Establish methods, procedures, and recommendations for providing field collected data to designers, users, manufacturers, and installers of system.

4. Standard 135-2004 – BACnet® – A Data Communication Protocol for Building Automation and Control Networks (ANSI Approved)
    - The purpose of this standard is to define data communication services and protocols for computer equipment used for monitoring and control of HVAC&R and other building systems and to define an abstract, object-oriented representation of information communicated between such equipment, thereby facilitating the application and use of digital control technology in buildings.
    - This standard is under continuous maintenance, which is a process ASHRAE uses to keep standards current through the issuance of addenda, or revisions.

5. ASHRAE Standard 140-2004 “Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs”
    - This standard specifies test procedures for evaluating the technical capabilities and ranges of applicability of computer programs that calculate the thermal performance of buildings and their HVAC systems.
    - These standard test procedures apply to building energy computer programs that calculate the thermal performance of a building and its mechanical systems. While these standard test procedures cannot test all algorithms within a building energy computer program, they can be used to indicate major flaws or limitations in capabilities.

6. ASHRAE Standard 147-2002 “Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems”
    - This standard establishes practices and procedures that will help air-conditioning equipment designers, installers and operators reduce the inadvertent release of halogenated refrigerants.

- This standard is under continuous maintenance, which is a process ASHRAE uses to keep guidelines and standards current through the issuance of addenda, or revisions.

7. ASHRAE Standard 150-2000 “Method of Testing the Performance of Cool Storage Systems”
    - This standard prescribes a uniform set of testing procedures for determining the cooling capacities and efficiencies of cool storage systems.

8. ASHRAE Standard 151-2002 “Practices for Measuring, Testing, Adjusting, and Balancing Shipboard HVAC&R Systems”
    - This standard provides uniform and systematic practices for making measurements in testing, analyzing, balancing, and reporting the performance of the heating, ventilation, air-conditioning, and refrigeration (HVAC&R) systems on board ships.

<u>Books</u>

1. CIBSE 2000 “Testing Buildings for Air Leakage, TM23”

Occupancy and Operations Phase

<u>ASHRAE Publications:</u>

1. ASHRAE Guideline 4-1993 “Preparation of Operating and Maintenance Documentation for Building Systems”
    - This guideline for the preparation of operating and maintenance (O&M) documentation for building systems complements ASHRAE Guideline I, The HVAC Commissioning Process.

Web Sites

1. www.wbdg.org
2. www.nibs.org
3. www.ashrae.org
4. www.bxca.org
5. www.usgbc.org
6. www.peci.org
7. www.energy.state.or.us/energy/cons/bus/comm/commcost.shtml
8. www.gsa.gov/
9. www.energy.ca.gov
10. www.cacx.org
11. www.doe.gov
12. www.nist.gov
13. www.energy.state.or.us/energy/cons/bus/comm/commsave.shtml
14. www.eere.energy.gov/building/info/operate/buildingcommissioning
15. www.cx.engr.wisc.edu

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

INFORMATIVE ANNEX R
INTEGRATION REQUIREMENTS

This annex provides information on training requirements for HVAC&R systems and assemblies. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X and other applicable commissioning technical guidelines tailored to their specific projects.

This Annex 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 dependant 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 following table from NIBS Guideline 3-2006 depicts some of the components and subsystems for a building which need to function and be 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 verity the installation matches the OPR, BoD, and the construction contract documents.

Table from NIBS Guideline 3-2006

Integrated Systems	Major Systems	Components	
Mechanical	Controls	Programmable controllers Terminal equipment Sensors System points	Actuators Point verification Graphics
	Ventilation	Fans VSDs Welded ducts HEPAs	Ductwork Filters Air terminals Dampers
	Hydronics	Boilers Chillers Exchangers Coils Humidifier	Valves Piping Pumps VSDs Chemicals
	Specialty	Air and gas Nitrogen CO_2 Fuel oil	Sprinkler DX systems Furnaces
	Plumbing	Reverse osmosis Domestic water systems Emergency eye/shower	Water heaters Plumbing fixtures Sanitary/storm
Electrical	Normal Low/Hi Voltage	Switchgear Transfer switches Transformers Panels	Breakers Relays MCCs
	Emergency	Generator Transfer switches Transformers Panels	Breakers Relays MCCs UPS
	Lighting	**Normal** Panels Fixtures Relays Controls Breakers	**Emergency** Panels Fixtures Relays Controls Breakers
	Communication, Security and Life Safety	Intercom PA system Fire alarm	Security Bio alarm
Architectural/ Structural	Structure	Containment Coatings (epoxy) Special floorings	Foundation Curtain wall Finish hardware Insulation Air barrier Windows Doors Roof Walls
	Mechanical Equipment	Hoists Elevators & escalators Dock levelers Prefab walk-in Freezers and coolers	Fume hoods BSCs Autoclaves Water purifier Glasswash Lab casework

ANNEX R from NIBS Guideline 3-2006

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.

	Material/System Type or Criteria	Inter-relations	Architectural Issues	Structural Issues	Mechanical Issues	Electrical Issues	*Comments*
A	**Heat Flow Control**						
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 affective 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 electrical service and distribution	
A.3	Relationship of Structure to Thermal Envelope						
B	**Air flow Control**						
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 accomodated in air tight barrier.	May require differential pressurization schemes to control direction of air flow.	Difficulty in sealing penetrations for electrical boxes may require consideration of outlet locations.	
B.3	Natural Ventilation						
C	**Water Vapor Flow Control**						
C.1	Vapor Retarder	B.1, D.1				Difficulty in sealing penetrations for electrical boxes may require consideration of outlet locations.	
C.2	Self-Drying Assemblies		Permeance of layers of envelope assemblies must be carefully studied to allow drying.	Structural members may need extra corrosion protection if located in concealed construction which may be wet at times.	Size of HVAC system will need to accommodate removal of moisture from exterior enclosures.		
D	**Rain Penetration/Water Control**						
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	Savings in electrical service from reduced HVAC may be offset by need for more artificial lighting	

					resulting HVAC system size.		
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.	
E	**Light, Solar and other Radiation Control**						
E.1	Daylighting		Walls and/or roof require large glazed areas. Tinted, spectrally selective or other special glass may be required. Light shelves or other devices may be required to maximize area of building affected by daylighting. Glare control and shading become more important with increased glazing.	Large glazed openings may require special framing in enclosure assemblies. Sunshading devices may impose difficult cantilever loads.	Study required to balance effectiveness of daylighting to reduce heat gain from artificial lighting versus increased heat gain/loss resulting from glazing. Large areas of glazing may need to be addressed to minimize asymmetrical radiant heat loss of occupants adjacent to glass. (i.e. baseboard radiation	May reduce size of main electrical service and distribution but may increase if balance of heat gain/loss is not optimized. BAS may get more complicated.	May have a substantial positive impact on user psychological comfort.

					and/or continuous slot diffusers)		
E.2	Shading						
E.3	Glare Control						
E.4	Photovoltaic Generation						
E.5	Radio Frequency/Electromag-netic Interference Control						
	Green Roof		Roof membrane is on the conditioned side of roof insulation, serving also as air barrier and vapor retarder. Roof membrane must be more dependable, similar to waterproofing, because of difficulty to access for future repairs.	Structure must support weight of soil and retained water	HVAC system may be reuduced from decreased heat gain and thermal mass		
F	**Noise and Vibration Control**						
F.1	Acoustic Isolation		High frequency isolation requires mulitple layers. Low frequency sound requires mass Windows and glazing may require special details and multiple layers of special glass.	Structure will need to support additional mass if needed for isolation. Vibration isolation of structure and substructure may be required.	Louvers and similar penetrations through enclosure will need special detailing for isolation. Chillers, air handlers and other sources of noise may need to be attenuated.	Generators and other sources of noise may need to be attenuated.	
F.2	Vibration Control						
G	**Fire Control**						
G.1	Passive Fire Protection						
G.2	Active Fire Protection		Systems must			Active systems	

			be coordinated to remain concealed, especially if heads are required on exterior of building. Wet systems on exposed side of thermal envelope need protection.			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						
H	**Structural Performance**						
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						
I	**Durability**						
I.1	Life Span						
I.2	High Reliability						
I.3	Microbial Growth Resistance						
J	**Aesthetics**						
K	**Value**						

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INFORMATIVE ANNEX S
INTERFERENCE AND COORDINATION WITH OTHER
SYSTEMS AND ASSEMBLIES

This annex provides information on training requirements for HVAC&R systems and assemblies. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-200X and other applicable commissioning technical guidelines tailored to their specific projects.

This annex addresses coordination issues that are part of every project, from simple to complex. Conflicts between building elements and services can quickly multiply during the design phase and can become enormous challenges for the design team to resolve. Building services may include HVAC&R&R, electrical, communications, plumbing and other building systems. This adds cost to the design effort when redesign becomes necessary to mitigate conflicts. In addition, when conflicts are discovered during the construction phase, redesign costs and change order requests can quickly deplete project budget reserves. This is a leading cause of dissension between Owner, Design Team and Construction Team.

Listed below are recommendations for avoiding and/or minimizing conflicts to ensure building elements and services will fit into available spaces and are accessible for service and maintenance during building occupancy.

1. Review design drawings to identify potential conflict between HVAC&R systems and work of other Trades (plumbing, fire protection, electrical, etc.).
2. Consider how HVAC&R work will interface and conform with building elements
3. Verify that:
    a. HVAC&R floor plans match architectural.
    b. HVAC&R ducts, piping and other elements do not conflict with architectural features or structural members.
    c. Adequate ceiling height exists at worst-case duct intersection or largest beam.
    d. Structural supports required for HVAC&R equipment are indicated on structural drawings.
    e. Dampers are indicated at smoke and fire walls.
    f. Diffuser locations match architectural reflected ceiling plans.
    g. Openings for roof penetrations (ducts, fans, etc.) are indicated on structural roof plans.
    h. Ductwork is correctly sized and fits in the space available.
    i. Notes are referenced.
    j. Air conditioning units, heaters, and exhaust fans match architectural roof plan locations.
    k. Mechanical equipment will fit in spaces allocated and that there is room for maintenance such as removing filters, coils, fans, tubes or other elements.

l. Horsepower ratings, phases and voltages of major items of equipment on mechanical and electrical drawings and specifications match.
m. Thermostat locations have been coordinated with architectural drawings.
n. System control panel locations are shown and coordinated with architectural drawings and other systems and assemblies.
o. Clearance in front of electrical device terminal connections is in compliance with National Electrical Code.

4. Implementation:
    a. Plan the placement of HVAC&R elements into project design documents with consideration for sharing space requirements of plumbing, fire protection, electrical and building elements.
    b. Ensure that the HVAC&R commissioning process is compatible with, and is fully integrated with the Total Building Commissioning process.
    c. Sequence of Priorities For Installation:

Ductwork	Keep as high as possible; close to floor slab above or at top of ceiling cavity..
Hydronic Water Piping	Keep as high as possible; close to floor slab above or at top of ceiling cavity.
Hydronic Steam Piping	Keep as high as possible; coordinate for pitch required in direction of flow.
Steam Condensate Piping	Keep as high as possible; gravity flow requires piping to run below steam supply piping; coordinate for pitch required in direction of flow.
Pumped Steam Condensate	Keep as high as possible; close to floor slab above or at top of ceiling cavity.
Pumped Condenser Water Piping Return to Cooling Tower	Keep as high as possible; close to floor slab above or at top of ceiling cavity.
Gravity Flow Condenser Water Piping Supply From Cooling Tower	Keep as high as possible; gravity flow requires piping to be coordinated for pitch in direction of flow.
Domestic Water Piping	Keep as high as possible; close to floor slab above or at top of ceiling cavity.
Storm and Waste Piping	Keep as high as possible; coordinate for pitch required in direction of flow.
Fire Sprinkler Piping	Run below main runs of ductwork or at mid-level of ceiling cavity.
Electrical Conduits	Keep as high as possible; close to floor slab above or at top of ceiling cavity.
Electrical Fixtures	Dedicated to first 6 to 8 inches in ceiling cavity above suspended ceiling.
Moveable Partitions	Require attachment and support from floor slab above
Fire Walls and Smoke Partitions	Penetrations require fire-seal treatment and fire/smoke dampering.

5. See included Interdisciplinary Coordination and Ceiling Section Detail developed for a typical project (Figure 1). This detail, if included in the construction documents, can be beneficial in establishing coordination guidance and reduce installation conflicts during the Construction Phase.

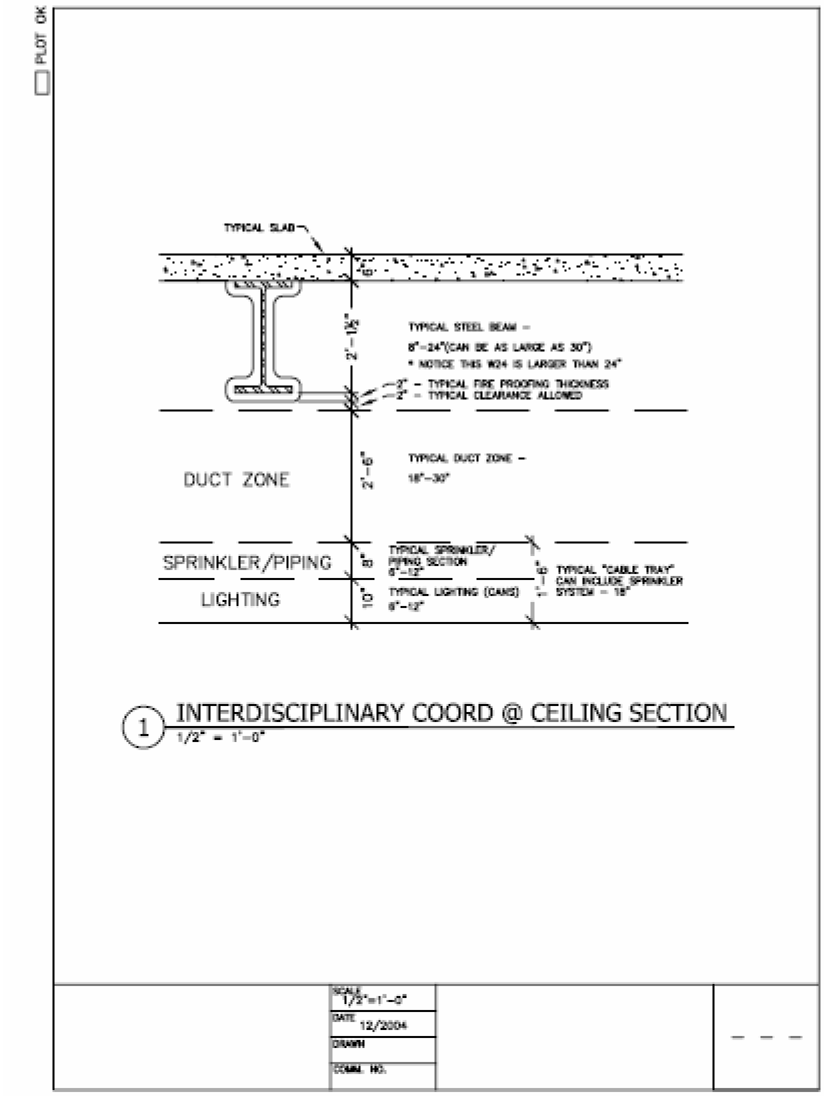


Figure 1 -- Typical Interdisciplinary Coordination and Ceiling Section Detail on Drawings

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

INFORMATIVE ANNEX T
COMMUNICATIONS: WHAT, WHEN, AND WHO

This annex provides communication guidance to assist in implementing Guideline 1-2006 as part of the commissioning process in ASHRAE Guideline 0-2006. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-2006, and applicable commissioning technical guidelines tailored to their specific projects.

This annex provides a set of flow diagrams indicating the requirements for various commissioning process activities and deliverables.

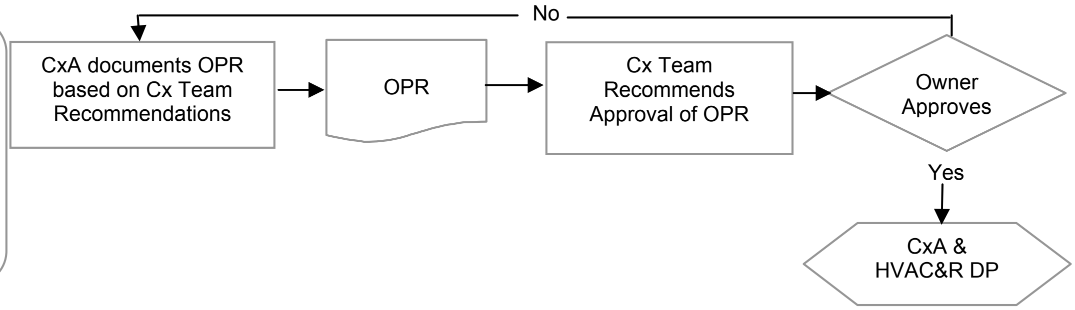
They include:

Flow Diagram Number	Topic
T-1	Owner's Project Requirements (OPR)
T-2	Commissioning Plan (CxPlan)
T-3	Submittals
T-4	O&M Requirements
T-5	Record Documents
T-6	Training Requirements
T-7	Basis of Design (BoD)
T-8	Systems Manual

Figure T – 1
OWNER PROJECT REQUIREMENTS (OPR)

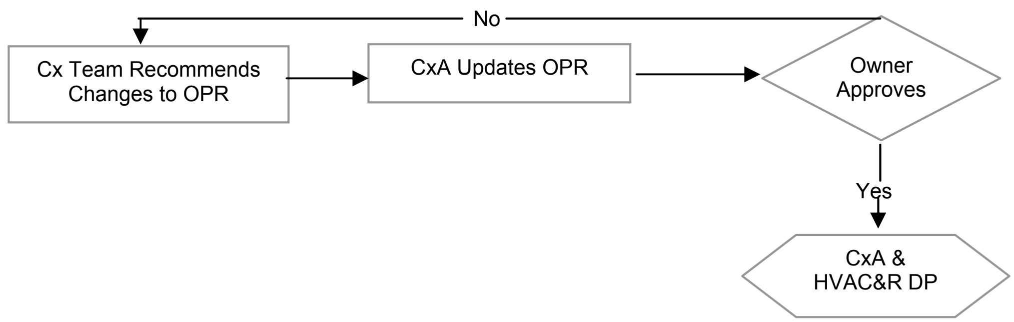
PREDESIGN PHASE

Commissioning (CX) Team
Owner Project Manager
Owner Controls Technician
Owner HVAC&R Technician
Facilities Engineer
HVAC&R Design Professional (DP)
Architect
Owner Designated User(s)
Commissioning Authority (CxA)



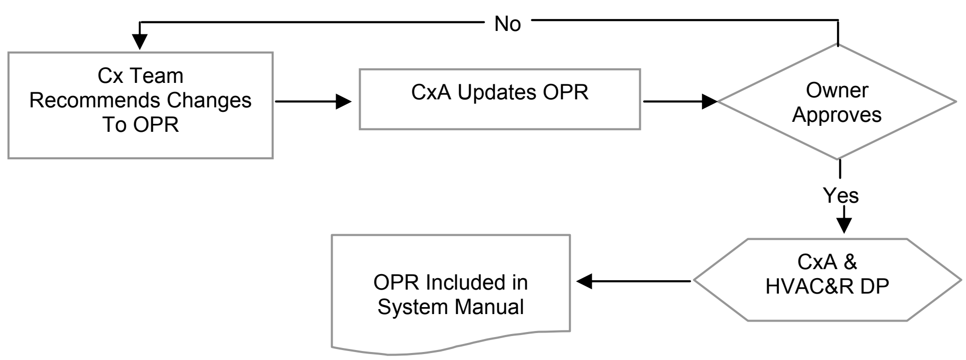
DESIGN PHASE

(CX) Team
Owner Project Manager
Owner Controls Technician
Owner HVAC&R Technician
Facilities Engineer
HVAC&R Design Professional
Architect
Owner Designated User(s)
Commissioning Authority



CONSTRUCTION PHASE

(CX) Team
Owner Project Manager
Owner Controls Technician
Owner HVAC&R Technician
Facilities Engineer
HVAC&R Design Professional
Design Specialists
Architect
Owner Designated User(s)
GC/CM
Mechanical Contractor
Equipment Suppliers
Commissioning Authority



OCCUPANCY & OPERATIONS PHASE

(CX) Team
Owner Project Manager
Owner Controls Technician
Owner HVAC&R Technician
Facilities Engineer
HVAC&R Design Professional
Architect
Commissioning Authority

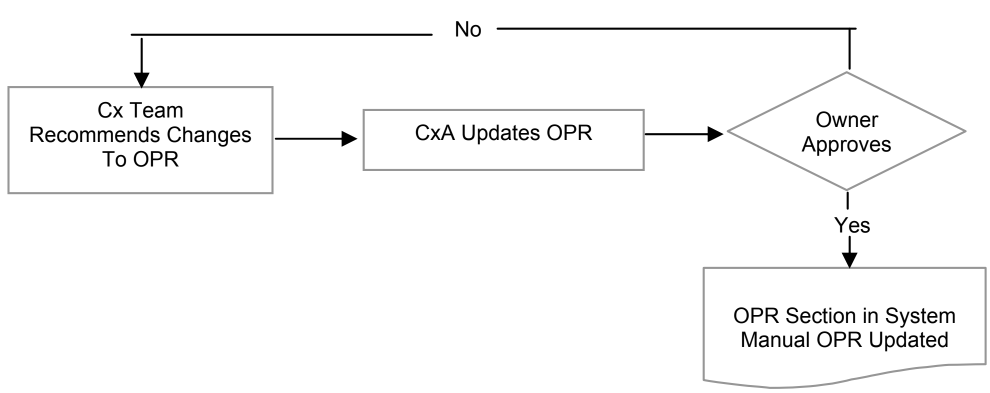


Figure T – 2
COMMISSIONING PLAN (Cx Plan)

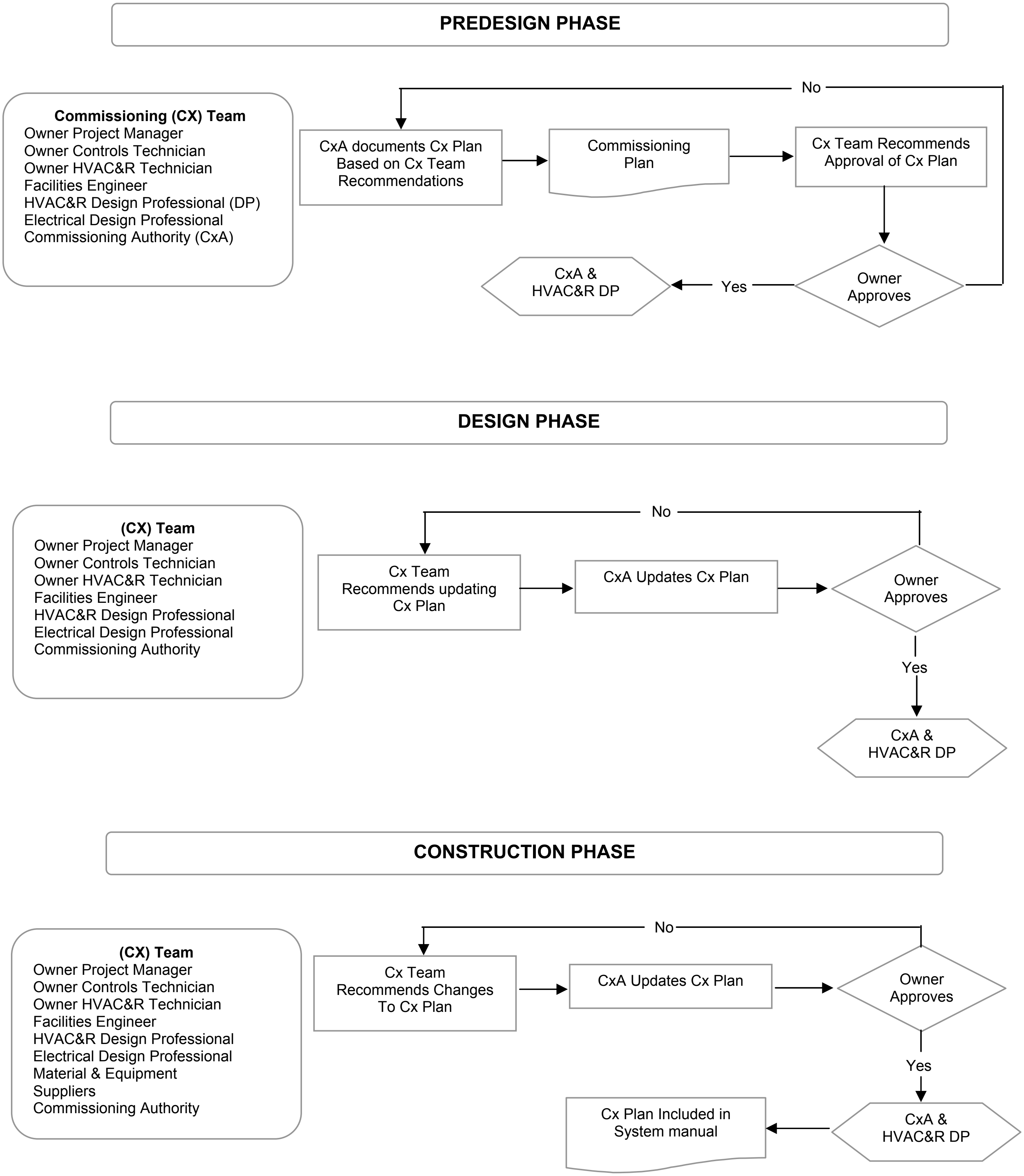


Figure T – 3
BASIS of DESIGN (BoD)

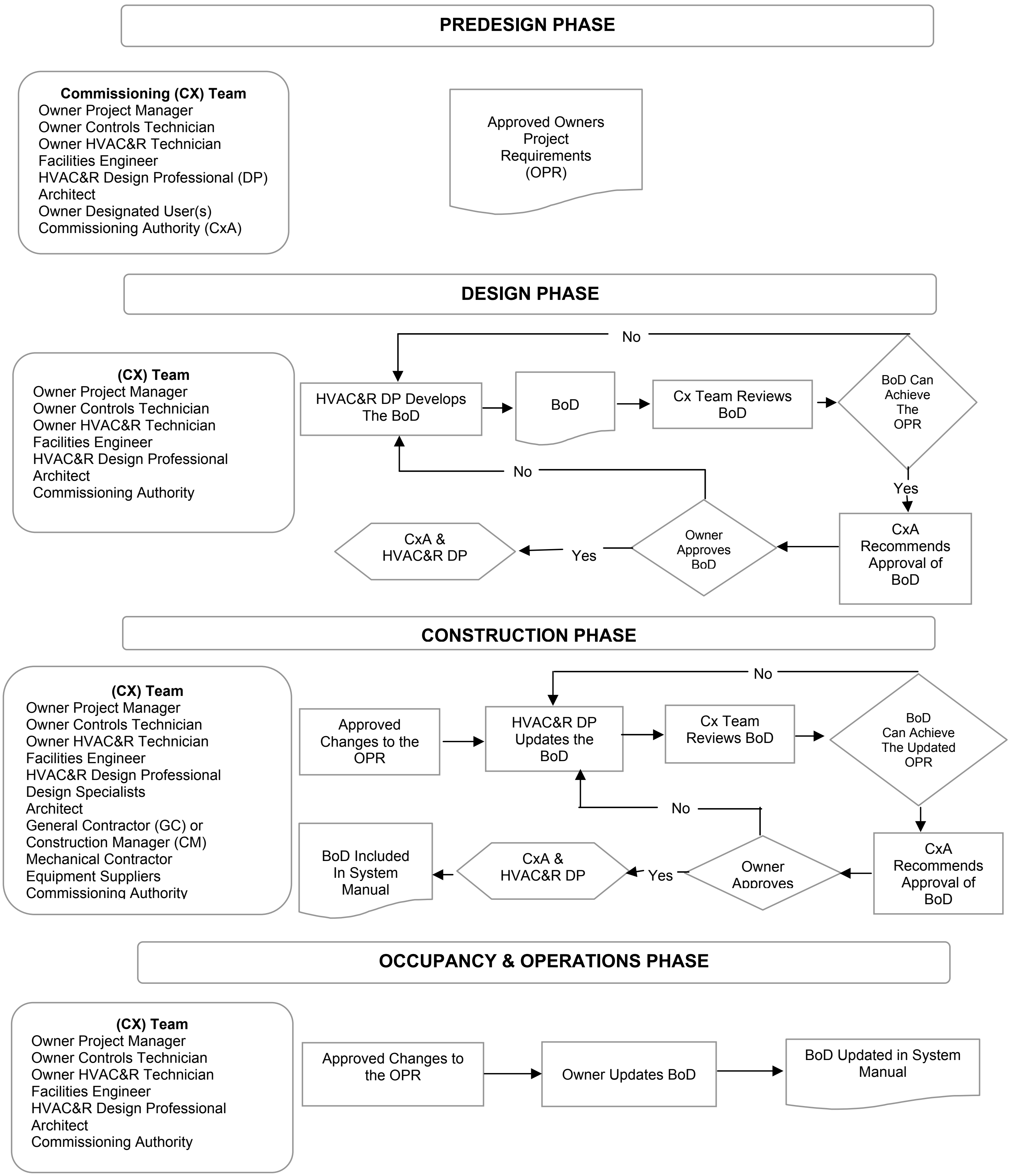


Figure T – 4
SUBMITTALS REQUIREMENTS

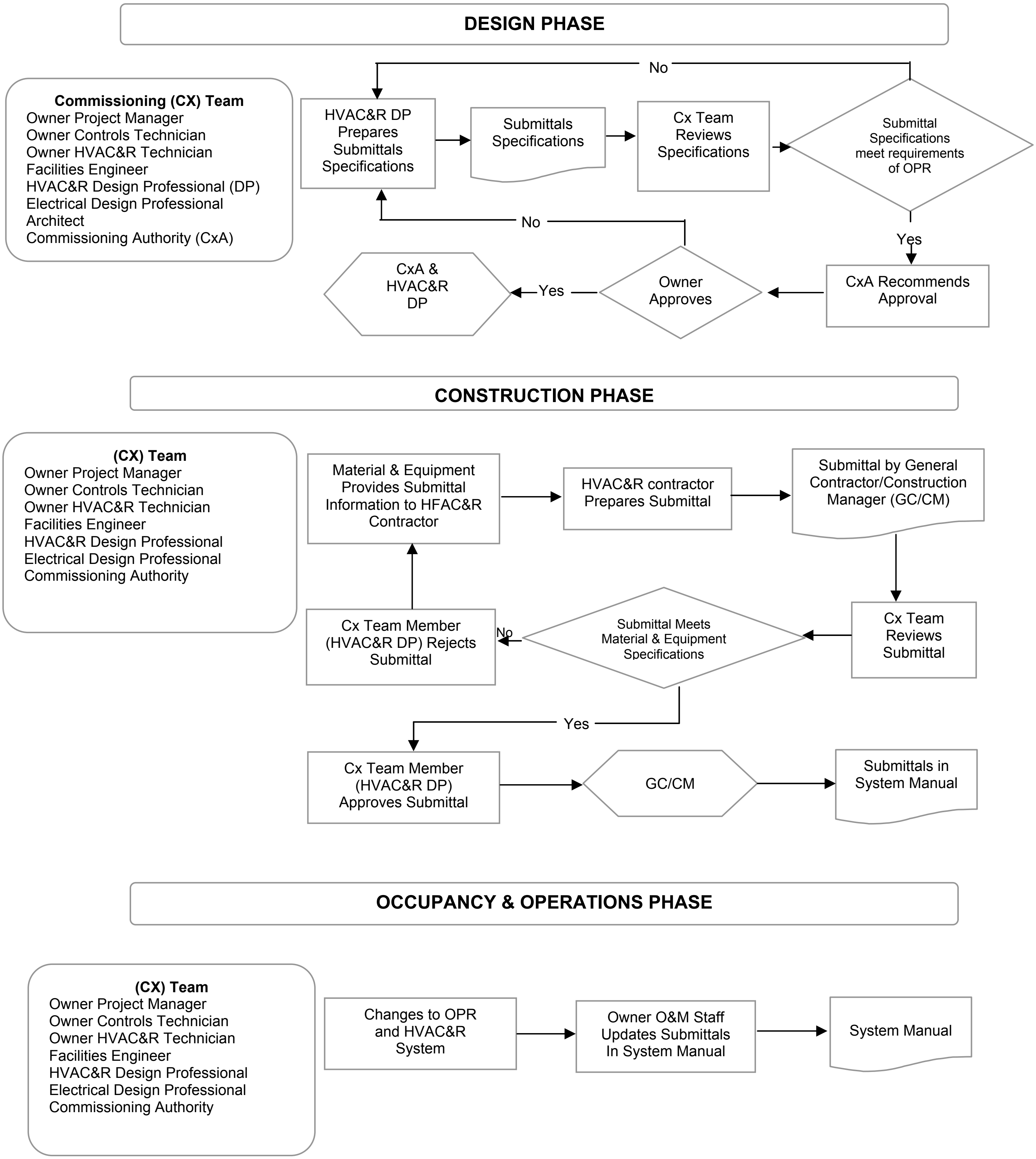


Figure T – 5
OPERATION & MAINTENANCE (O&M) REQUIREMENTS

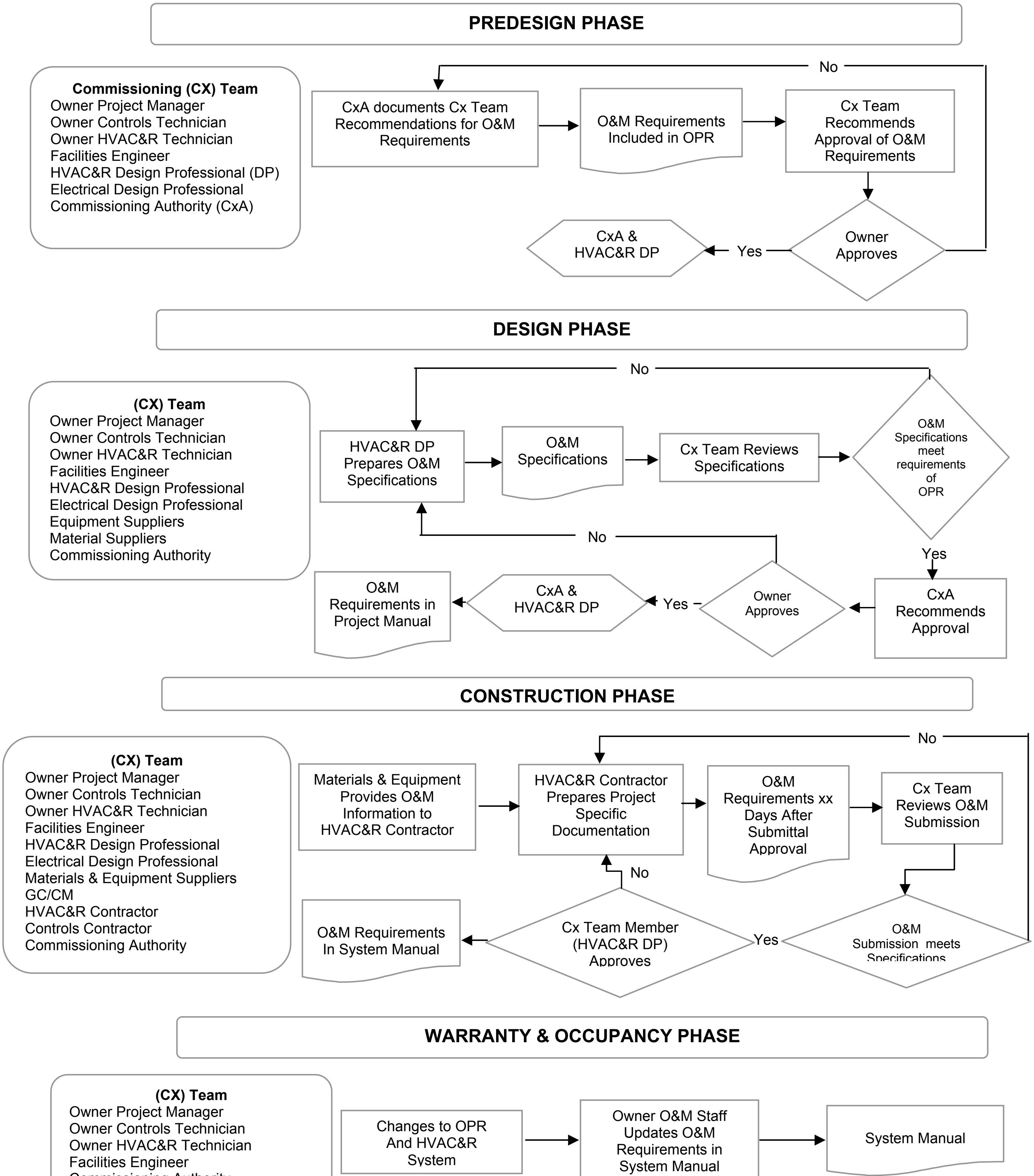


Figure T – 6
RECORD DOCUMENTS

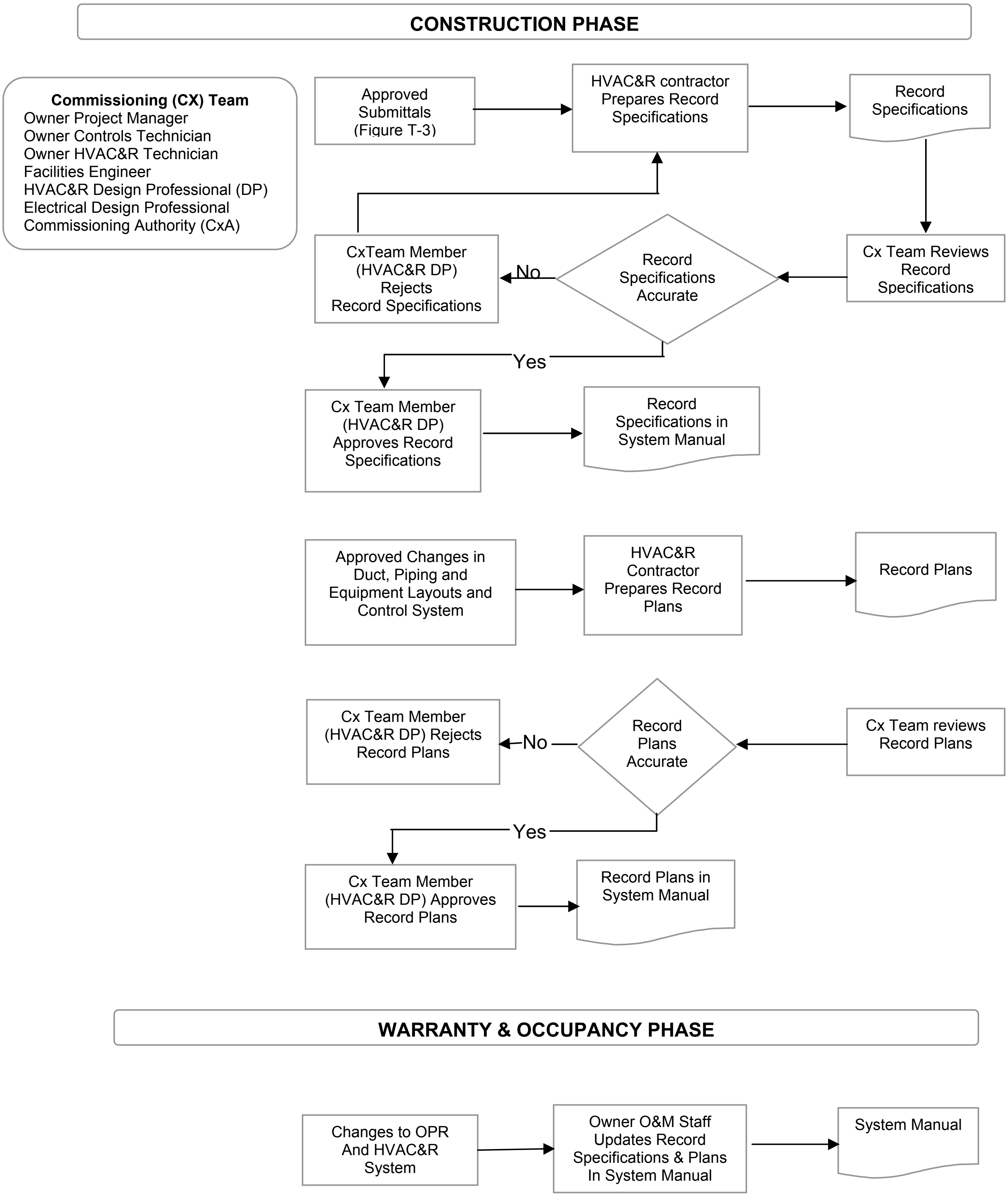


Figure T – 7
TRAINING REQUIREMENTS

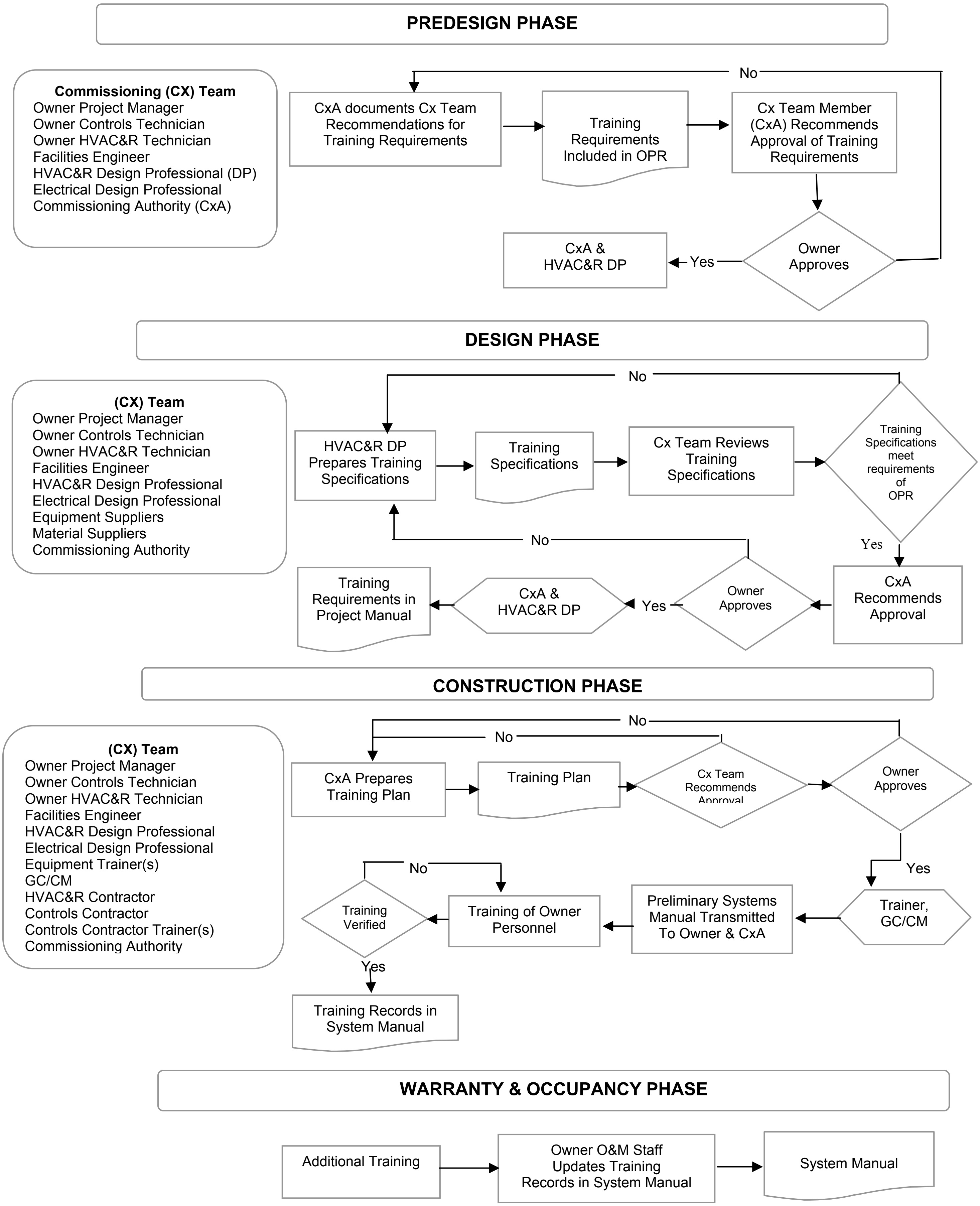
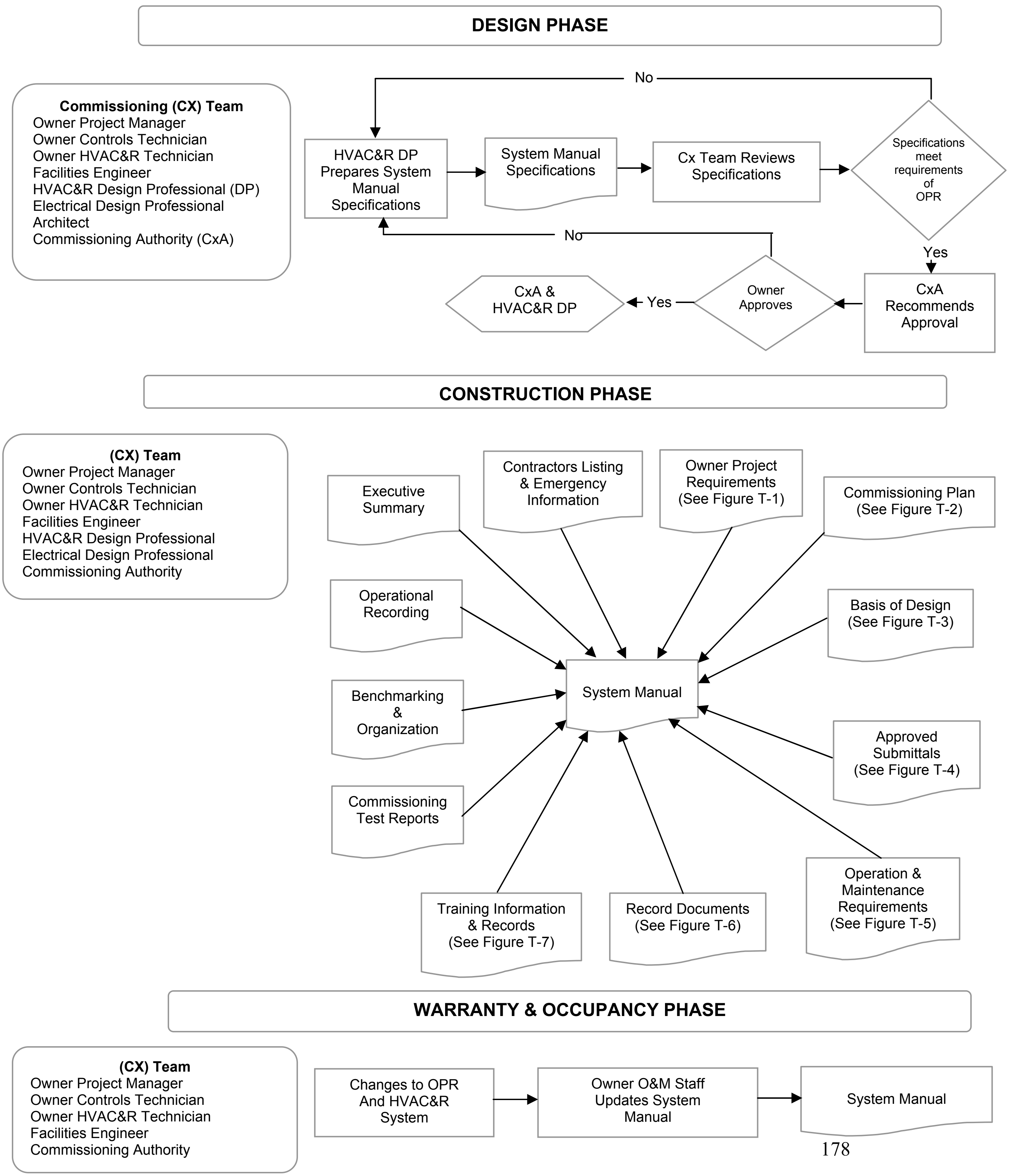


Figure T – 8
SYSTEM MANUAL



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INFORMATIVE ANNEX U

TEST PROCEDURES AND DATA FORMS

This annex provides an example of how to implement part of Guideline 1-2006. It is not intended to be a comprehensive representation or a best practice example. Practitioners applying the Commissioning Process should carefully follow Guideline 0-2005, Guideline 1-2006, and applicable commissioning technical guidelines tailored to their specific projects.

This sample commissioning process test procedure is to be accomplished during any season whenever the project is ready for commissioning process test implementation. The intent of accomplishing the complete commissioning process test procedure prior to owner acceptance is to verify to the best of our ability achievement of the OPR. Some of the individual scenarios will need to be accomplished during other seasons to verify achievement of the OPR during seasonal ambient conditions.

Comfort OPR Commissioning Process Test Procedure

Test Number: _______ Date: _______________ Time: __________

_____ New _____ Retest

Background: Verifying achievement of the comfort OPR prior to occupancy is accomplished through the execution of this commissioning process test procedure, which is composed of several operational scenarios. It is important to understand that this final commissioning process test procedure is focused on achievement of the OPR, which means evaluating the performance of the facility, not a single component or system.

This scenario approach works in the context that the individual components and systems have been verified throughout design and during construction from delivery through startup utilizing the construction checklists. This test procedure is accomplished to verify achievement of success (OPR) – it is not the intent to identify a significant number of issues at this stage in construction, because the commissioning process implementation should have identified and resolved the majority of issues earlier in the project.

OPR to be Verified: Comfort is the focus of this commissioning process test procedure. Comfort has been defined by the owner in the OPR as consistent temperature from space to space to avoid having occupants feel variations in temperature as they move throughout the facility.

Facility Scenarios: The operational scenarios to be implemented through this commissioning process test procedure to verify achievement of the comfort OPR are:

1. Morning Warm-up – Cloudy Day: For this scenario, the perimeter spaces are 10°F cooler than set point and interior are 2-5°F cooler than set point.

2. Morning Warm-up – Clear Day: For this scenario, the west perimeter is 10°F cooler than set point, the interior spaces 2-5°F cooler than set point, and the East perimeter 0-5°F warmer than set point.

3. Morning Cool-down – Cloudy Day: For this scenario, the perimeter is 10°F warmer than set point and the interior 2-5°F warmer than set point.

4. Morning Cool-down – Clear Day: For this scenario, the East perimeter is 10°F warmer than set point, interior is 2-5°F warmer than set point, and West perimeter 0-5°F warmer than set point.

5. Peak Cooling: For this scenario, all spaces start at 5-10°F warmer than set point.

6. Peak Heating: For this scenario, all spaces start 5-10°F cooler than set point.

7. Afternoon Cooling: For this scenario, the West perimeter is 5°F warmer than set point, remaining spaces at set point.

8. Conference Room Load: For this scenario, the conference room is 10°F warmer than set point, other spaces 2-5°F warmer than set point.

Systems/Assemblies/Equipment/Components Evaluated: The comfort OPR is impacted by most systems and assemblies in the facility. The following systems and assemblies are the primary ones that are evaluated during completion of this commissioning test procedure:

- Chilled Water System
- Hot Water System
- Air Distribution System
- Air Handling Unit
- Variable Air Volume Terminal Units
- Room Air Diffusers
- Exterior Envelope
- Interior Partitions
- Building Automation Management System (BAMS)

Ambient Conditions: The scenarios that are to be implemented under this commissioning test procedure are intended to evaluate the performance of the entire facility to maintain consistent temperatures from space to space. Each scenario starts with spaces at realistic initial conditions that are expected to occur sometime throughout the year. Implementing this commissioning test procedure then evaluates how quickly and effectively the systems respond to achieve consistent space temperatures. Evaluating the recorded results will determine if consistent temperatures are expected to be maintained under actual operation throughout the year.

While the ambient conditions will impact the results of the test (e.g., if it is hot outside, the heating tests will not be as realistic as desired), the scenarios have been created to limit this impact. Ideally, this commissioning test will be accomplished under non-peak outdoor design conditions to limit impact on overall results. However, if the test is being performed during a peak outdoor condition, then the similar season scenarios will be accomplished during the peak outdoor conditions (e.g., the cooling scenarios) and the opposite season scenarios (e.g., the heating scenarios) will be accomplished at night to limit ambient conditions on test results.

Pre-requisites: The following pre-requisites must be accomplished prior to implementing this commissioning test:

- Construction checklists for the systems, assemblies, equipment and components must be completed by the contractor and verification by the commissioning authority accomplished.

- The testing, adjusting and balancing (TAB) work must be completed and the final report verified by the commissioning authority.

Items to be Recorded: The system response time to a change for this facility is estimated to be 5 minutes (the time it takes for a change to be seen in the space once the set point has been changed). Therefore, the frequency of recording data should be less than the system response time to be able to identify anomalies and issues. For this commissioning test the frequency of recording data is to be every 2 minutes.

The following items are to be recorded:

- Chilled water system
  - Chilled water supply temperature
  - Chilled water return temperature
  - Condenser water supply temperature
  - Condenser water return temperature
  - Primary and secondary pump status
  - Secondary pump speed
  - System pressure
  - Chiller electrical usage
- Hot water system
  - Hot water supply temperature
  - Hot water return temperature
  - Primary and secondary pump status
  - Secondary pump speed
  - System pressure
  - Boiler gas usage
  - Stack temperature
- Air handling units
  - Supply air temperature
  - Return air temperature
  - Mixed air temperature
  - Chilled water valve position
  - Hot water valve position
  - Supply fan speed
- Variable air volume terminal units

- Airflow
- Reheat valve position
- Supply air temperature
- Mode of operation

▪ Spaces
  - Set point
  - Temperature
  - Humidity (where sensor present)

▪ Outdoors
  - Temperature
  - Humidity
  - Unique conditions (cloudy, precipitation, wind)

Participants: The following participants shall be present during the implementation of this commissioning test:

- Commissioning Authority – oversees and directs the test and records the results.
- BAMS Contractor – helps in setting up and switching scenarios and provides electronic files of recorded information.
- Operation and Maintenance Personnel – helps in recording results and implementing the test.

The following participants will be invited, but are not required to attend:

- Mechanical Contractor – technician may be required to fix items to continue implementing the test.
- Electrical Contractor – technician may be required to fix items to continue implementing the test.
- General Contractor – to understand tests and results in case of failure.
- Design Professionals – to understand tests and results in case of failure.

Expected Performance: The systems should be able to achieve stable, consistent space temperatures within 20 minutes from the change of set point (this is based on an air-change-rate of 3 per hour on average). Therefore, the expected performance is that all space temperatures should be at set point within 20 minutes of initiating the scenario (within set point means ±2°F of set point for any space due to accuracy of the space sensors).

Test Procedures: The following table shall be followed in implementing and recording the results of this commissioning process test procedure, with occupied cooling and heating set point being 74°F:

Test	Step	Expected	Actual	Pass/Fail
Morning Warm-up – Cloudy Day				
	Set Perimeter Spaces to 64°F (10°F cooler than set point)			
	Set Interior Spaces to 69°F (5°F cooler than set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			
Morning Warm-up – Clear Day				

Test	Step	Expected	Actual	Pass/Fail
	Set South, West, and North Perimeter Spaces to 64°F (10°F cooler than set point)			
	Set East Perimeter to 79°F (5°F warmer than set point)			
	Set Interior Spaces to 69°F (5°F cooler than set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			
Morning Cool-down – Cloudy Day				
	Set Perimeter Spaces to 84°F (10°F warmer than set point)			
	Set Interior Spaces to 79°F (5°F warmer than set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			
Morning Cool-down – Clear Day				
	Set South and North Perimeter and Interior Spaces to 79°F (5°F warmer than set point)			
	Set East Perimeter to 84°F (10°F warmer than set point)			
	Set West Perimeter to 76°F (2°F warmer than set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			
Peak Cooling				
	Set All Spaces to 84°F (10°F warmer than set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			
Peak Heating				
	Set All Spaces to 64°F (10°F cooler than set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			
Afternoon Cooling				
	Set West Perimeter to 79°F (5°F warmer than set point)			
	Sell All Other Spaces to 74°F (at set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			
Conference Room Load				
	Set Conference Room to 84°F (10°F warmer than set point)			
	Sell All Other Spaces to 78°F (3°F warmer			

Test	Step	Expected	Actual	Pass/Fail
	than set point)			
	Record Results			
	Record Time to Stability	20 minutes		
	Record Issues Identified			

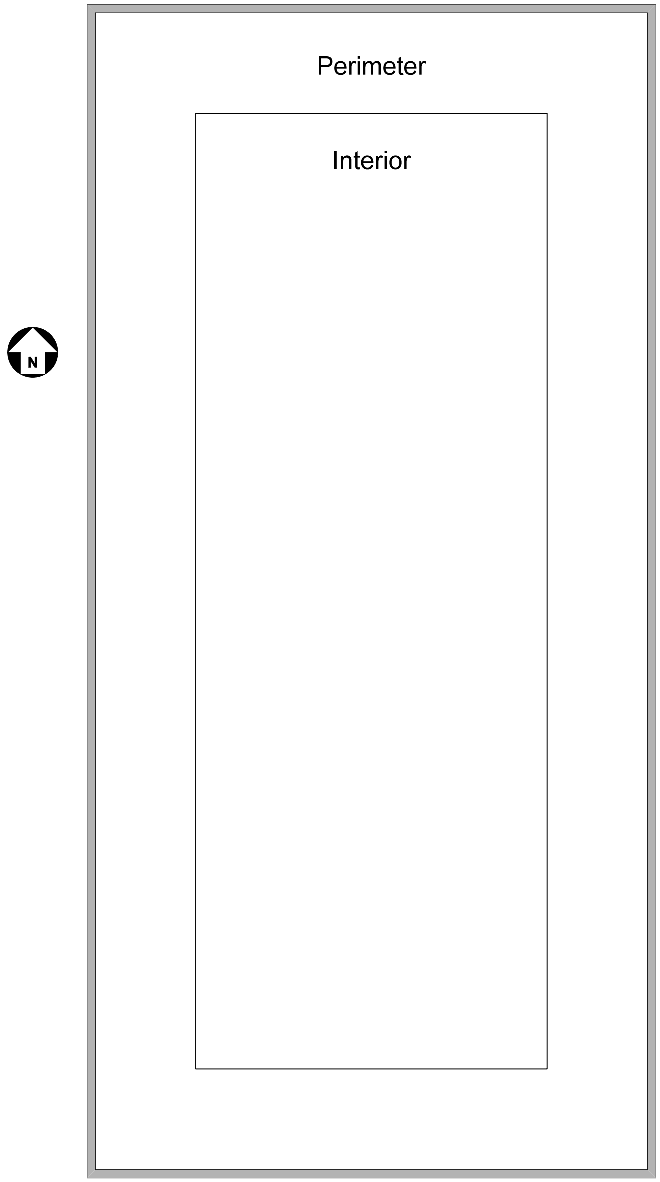

Figure 1: Building Layout for Comfort OPR Commissioning Test

<u>Other Observations:</u> The following observations were noted during the implementation of this comfort OPR commissioning process test procedure:

 # Observation

1 ____

2 ____

3 ____

4 ____

5 ____
6 ____
7 ____

Issues: The following issues were identified during the implementation of this comfort OPR commissioning process test procedure and require follow-up (the detailed issue should be entered into the issues database).

#	Issue Description	Person Responsible	Response Date
1			
2			
3			
4			
5			

Signatures: The following shall be completed after implementation of the test procedure.

Signature

Commissioning Authority

Date/Time

Signature

BAMS Contractor

Date/Time

Signature

Mechanical Contractor

Date/Time

Signature

Electrical Contractor

Date/Time