

ASHRAE Guideline 1-1996

(Supersedes ASHRAE Guideline 1-1989)



ASHRAE[®] GUIDELINE

The HVAC Commissioning Process

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(This foreword is provided for information only and is not part of this guideline.)

FOREWORD

This guideline places a high emphasis on commissioning as a process. Its goal is a fully functional, fine-tuned HVAC system with complete documentation and an adequately trained operating and maintenance staff. It provides a structured methodology for implementing the commissioning process for HVAC systems and components in new and existing buildings. It provides guidance for owners, design professionals, construction managers, contractors, manufacturers, suppliers, and building system operating and maintenance personnel to achieve quality and efficient and effective HVAC systems. Emphasis is placed on the owner's program, design intent, documentation, and the proper transfer of ideas and design concepts from one party to the next. It also requires that the building operation and maintenance personnel be provided with full system training and receive documentation on how the system was designed, installed, and intended to operate. Owners can use the process to achieve quality from the start in lieu of inspecting for quality or modifying the system after the facility is occupied.

Owners and design professionals may implement the commissioning process at any stage of the project. This guideline recommends that commissioning be implemented early in the program phase, and it provides general information required in the full commissioning process from program phase to post-acceptance. The body of the guideline provides the general structure and requirements to carry out the commissioning process.

This guideline strongly suggests that a new professional, the commissioning authority, be part of the HVAC project process. The commissioning authority represents the owner's needs from project program phase through occupancy. This is typically through the first year of operation; however, for complex and critical HVAC projects, the commissioning authority may continue with the project for a number of years. The commissioning authority is logically an employee of the owner; however, the authority can be an independent professional. Appropriate experience includes facilities operation and maintenance, design, testing-adjusting-balancing, construction management, and total quality.

Appendices have been included with this guideline to assist all participants in further understanding the commissioning process. They are based on specific project experience, with suggestions from experienced commissioning authorities and owners on ways to improve the current practice. They are not essential to implementing the requirements of the commissioning process, but they are deemed necessary if wide application of the commissioning process is to be a part of all HVAC projects. It is recommended that the appendices be used as guidance to develop documents and to define the owner's needs, design intent, Basis of Design, design concepts, verification and functional performance testing require-

ments, and operator training. However, the appendices are only general examples and should not be used in lieu of the guideline.

The commissioning process requirements that follow in clauses 5 through 10 have been structured to coincide with the phases of a typical design-bid-construct project. This includes program, design, construction, acceptance, and future modification. Clause 11 describes the requirements for a training program for operating and maintenance personnel for successful HVAC system performance. Clause 12 describes the documentation necessary to meet the guideline requirements given in clauses 5 through 10.

1. PURPOSE

The purpose of this guideline is to describe the commissioning process that will ensure heating, ventilating, and air-conditioning (HVAC) systems perform in conformity with design intent.

2. SCOPE

2.1 The procedures, methods, and documentation requirements in this guideline cover each phase of the commissioning process for all types and sizes of HVAC systems, from pre-design through final acceptance and post-occupancy, including changes in building and occupancy requirements after initial occupancy.

2.2 This guideline provides procedures for the preparation of documentation of

- (a) owner's assumptions and requirements;
- (b) design intent, Basis of Design, and expected performance;
- (c) verification and functional performance testing; and
- (d) operation and maintenance criteria.

2.3 This guideline specifically details the process for

- (a) conducting verification and functional performance testing and
- (b) maintaining system performance to meet the current design intent after initial occupancy.

2.4 This guideline includes a program for training of operation and maintenance personnel.

3. UTILIZATION

3.1 The implementation of the commissioning process will depend on the owner's requirements and how the project will be designed, built, and occupied. This guideline establishes procedures for implementation of the commissioning process no matter how the project is staged or scheduled or when the process is begun. It must be noted that if the commissioning process is initiated later than the program phase, some procedures listed in earlier phases will need to be performed.

3.2 The commissioning process for a project that is to be designed, built, and completely occupied in one continuous schedule will follow the procedures as presented in this guideline.

3.3 This guideline can also be applied to projects that will be completed in stages.

3.3.1 For staged projects, the commissioning process must be planned and implemented to accommodate the schedule while still delivering a fully functional, fine-tuned HVAC system for that portion of the project that is completed and occupied.

3.3.2 The commissioning process for staged projects will follow the procedures as presented in this guideline for that portion of the system that will be completed in each stage. Some procedures on previously completed and accepted portions of the system may be repeated to fine-tune the whole system completed to date.

3.3.3 All equipment, systems, controls, and interfaces for each portion of the staged project must be completed and operational in accordance with the contract documents before the acceptance procedures begin.

4. DEFINITIONS

4.1 Definition of terms used in this guideline may be found in *ASHRAE Terminology of Heating, Ventilation, Air Conditioning, & Refrigeration*.¹

4.2 Additional terms used in this guideline not found in the terminology handbook are defined in this clause.

acceptable performance: a component or system that is able to meet the specified requirements under all ranges of actual loads.

as-built records: documents that accurately represent the actual installed conditions, equipment, and systems, such as drawings, computer graphics, equipment data sheets, operation manuals, maintenance manuals, and the training program and videotapes.

Basis of Design: all information necessary to accomplish the design intent, including weather data, interior environmental criteria, other pertinent design assumptions, cost goals, and references to applicable codes, standards, regulations, and guidelines.

Certificate of Readiness: a document stating that all equipment, systems, and controls have been correctly installed; operated as specified; tested, adjusted, and balanced; and are verified as ready for functional performance testing and other acceptance procedures.

commissioning: the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent. In this guideline, commissioning begins with planning and includes design, construction, start-up, acceptance and training, and can be applied throughout the life of the building.

commissioning authority: the designated person, company, or agent who implements the overall commissioning process.

Commissioning Plan: a document defining the commissioning process, which is developed in increasing detail as the project progresses through its various phases.

commissioning report: the document that records the results of the commissioning process, including the as-built performance of the HVAC system and unresolved issues.

commissioning specification: the contract document that details the objective, scope, and implementation of the construction and acceptance phases of the commissioning process as developed in the design-phase Commissioning Plan.

commissioning team: those people responsible for working together in carrying out the commissioning process.

construction manager: the designated person, company, or agent who is responsible for managing the overall construction process.

design intent: a detailed explanation of the ideas, concepts, and criteria that are defined by the owner to be important. This typically is an expansion of the information provided in the Owner's Program.

design intent document: a detailed written document, evolving throughout the commissioning process, clearly defining items and criteria of the design intent.

functional performance testing (FPT): the process of determining the ability of the HVAC system to deliver heating, ventilating, and air-conditioning services in accordance with the final design intent.

Owner's Program: the document that outlines the owners overall vision for the facility and expectations of how it will be used and operated.

Systems Manual: a composite document that expands the scope of the operation manual and maintenance manual developed in ASHRAE Guideline 4-1993 by including the additional information gathered by the commissioning process.

verification: that full range of checks and tests carried out to determine if all components, subsystems, systems, and interfaces between systems operate in accordance with the contract documents. In this context, "operate" includes all modes and sequences of control operation, interlocks and conditional control responses, and specified responses to abnormal or emergency conditions.

5. PROGRAM PHASE

5.1 Introduction

5.1.1 The HVAC commissioning process begins with the program phase. This process should begin as close to project inception as possible.

5.1.2 Objectives of the HVAC commissioning process during the program phase are to

- (a) document the owner's requirements as specified in the Owner's Program,
- (b) select the commissioning authority,
- (c) identify and assign responsibilities,
- (d) document the initial design intent, and
- (e) begin development of the Commissioning Plan.

5.1.3 Information gathered in this phase will be used to develop the system design and enable evaluation of system performance.

5.2 Program-Phase Procedure

5.2.1 Owner's Program

5.2.1.1 The Owner's Program outlines the owner's overall vision for the facility and expectations of how it will be used and operated. The Owner's Program should contain known goals and objectives, important items and criteria, and costs and other limitations. The Owner's Program may include building utilization, user needs, occupancy requirements, type of building construction, system functions, and energy, and air quality and environmental performance criteria. It should define the scope of the commissioning process and the preferred organizational structure and contain all requirements important to enable the development of the initial design intent document and Commissioning Plan. It is a critical document that forms the basis from which all other documentation is developed. An effective commissioning process is enhanced by quality information being provided in the Owner's Program.

5.2.1.2 The commissioning authority and the design team are selected at this time. It may also be possible to select the construction firm at this time.

5.2.1.3 The operations and maintenance (O&M) personnel should be identified at this time and be encouraged to lend their practical knowledge to ensure that important O&M issues are considered in the development of the HVAC system and the commissioning process, thus improving the final product.

5.2.2 Design Intent

5.2.2.1 Creating a clear design intent is the most critical aspect of the HVAC commissioning process. Design intent defines the benchmark by which the success of a project is judged.

5.2.2.2 The initial design intent document is a detailed explanation of the information developed in the Owner's Program. The initial design intent document should describe the facility's functional needs, intended levels and quality of environmental control, and environmental needs.

5.2.2.3 When approved, the design intent document shall be used as the starting point for the development of the Basis of Design as defined in clause 4 and referred to in case of ambiguities or uncertainties about project design. Changes to the design intent occurring during the course of the project

shall be documented, reviewed, and approved. The design intent document is to be included in the contract documents as a reference. As-built conditions are to reflect all implemented changes to fulfill the final design intent as described in the final design intent document. The final design intent document shall become part of the Systems Manual.

5.2.2.4 Refer to 12.2.2 for a detailed list of items to be included, as applicable, in the design intent document.

5.2.3 Commissioning Plan

5.2.3.1 The Commissioning Plan is a document, or group of documents, that defines the commissioning process at the various stages of project development. It is continually evolving and is expanded as the design and construction of the HVAC system progresses.

5.2.3.2 As the design concepts are being developed from the initial design intent document, a preliminary Commissioning Plan is developed that outlines the process required to commission the HVAC system. This plan should develop the extent of the commissioning process and communicate it to all project participants. It must include the scope of the process, the time required for completion, and training and staffing requirements. Refer to 12.2.3 for a detailed list of items to be incorporated as applicable.

5.2.3.3 The scope and potential cost of the commissioning process as outlined in the preliminary Commissioning Plan should be evaluated and approved.

5.2.3.4 The potential members of the commissioning team are identified in the preliminary Commissioning Plan. The team should include the owner, commissioning authority, design professional(s), operation and maintenance staff, contractors, vendors, and other specialists as deemed appropriate for the complexity of the project. The team may be expanded or modified as the project progresses.

5.2.4 Basis of Design

5.2.4.1 The Basis of Design shall respond to, and be consistent with, performance criteria specified in the design intent document. The Basis of Design will include the heating, ventilating, and air-conditioning requirements for each occupancy, activity, and/or physical area of the proposed facility with specific reference to ASHRAE or other applicable standards, local building codes, and environmental quality objectives. For further details refer to 12.2.4.

5.2.4.2 Since design intent may be revised and changes accepted as design concepts develop, the Basis of Design should be reviewed with regard to these changes and updated as needed.

5.2.4.3 The final versions of the design intent document and the Basis of Design shall be included in the design documents because of their importance.

5.2.5 HVAC System Design Concepts

5.2.5.1 Conceptual designs for HVAC systems that fulfill the Basis of Design shall be prepared to provide options to the owner for meeting the Owner's Program and design intent.

5.2.5.2 A written document is prepared defining design assumptions; building energy performance; performance standards of the proposed HVAC system; the most appropriate conceptual approach; space requirements for equipment, intakes, and exhausts; zoning; and other HVAC system requirements that affect building use and aesthetics.

5.3 Systems Manual

5.3.1 At this stage in the commissioning process, compilation of material for the Systems Manual begins. The Systems Manual is to provide to the owner information needed to understand, operate, and maintain each system and inform others about each system. Refer to 12.6.3 for a detailed list of items to place in the Systems Manual over the course of the project.

5.3.2 At this time, the Systems Manual will contain a statement that conveys the required functional operation of the HVAC and related life-safety systems in all normal and emergency modes of operation. Information on space requirements for equipment, intake and exhaust location limitations, zoning criteria, and other HVAC system requirements affecting building use and aesthetics should be included if applicable.

5.3.3 The initial design intent document shall be included in the Systems Manual.

5.3.4 The Systems Manual will be updated through all phases of the project.

6. DESIGN PHASE

6.1 Introduction

6.1.1 The design phase of the HVAC commissioning process begins with the preparation of schematic design documents.

6.1.2 The objectives of the HVAC commissioning process during the design phase are to

- (a) document the design intent as it evolves;
- (b) continue development of the Commissioning Plan;
- (c) develop the commissioning specification;
- (d) prepare contract documents that clearly reveal, describe, and fulfill the design intent;
- (e) review and accept contract documents for compliance with design intent; and
- (f) coordinate other mechanical, electrical, fire safety, and life-safety service requirements with HVAC layout, equipment, and systems.

6.2 Design-Phase Procedures

6.2.1 Documentation of Design Intent. Changes to the initial design intent occurring during the design phase shall be documented, reviewed, and approved. The revised design intent document shall become part of the contract documents.

6.2.2 Commissioning Plan During the design phase, the approved preliminary Commissioning Plan is expanded to detail the activities of all participants involved in the commissioning process. It must define the scope of work, the roles and responsibilities of each participant, and the organization, staffing, and scheduling of the process, providing sufficient

detail to guide the preparation of the commissioning specification. Refer to 12.3 for a detailed listing of the Commissioning Plan's content.

6.2.3 Commissioning Specification

6.2.3.1 The HVAC commissioning specification is part of the project specification. This is required to contractually implement the post-design phases of the process. The commissioning specification is a detailed description of the scope and objective of the commissioning process during the construction, acceptance, and post-acceptance phases of a project. It must specify the scope of work, roles, responsibilities, and requirements of each commissioning team member. It is needed by contractors to bid the services required. Refer to 12.3 for a detailed list. Refer to Appendix A6. 4 for a sample commissioning specification.

6.2.3.2 The commissioning specification shall detail the acceptance phase procedures for verification and functional performance testing, as well as other required acceptance-phase procedures. It must include a list of equipment and systems to be evaluated, along with checklist formats and sample test forms to clarify requirements.

6.2.3.3 The information developed in the Owner's Program will form the introductory summary of the commissioning specification.

6.2.3.4 The scope of work shall identify the required skills and qualifications of the commissioning team, including operation and maintenance personnel. It shall include a section for each trade involved in the construction of the HVAC system, detailing their scope of work in the commissioning process.

6.2.4 Preparation of Contract Documents. Contract documents shall be prepared that clearly reveal, describe, and fulfill the design intent document.

6.2.5 Review and Acceptance of Contract Documents

6.2.5.1 Contract documents shall be reviewed for compliance with the current design intent document, with the results documented and reported to the owner.

6.2.5.2 The contract documents are accepted or rejected by the owner or the owner's designee.

7. CONSTRUCTION PHASE

7.1 Introduction

7.1.1 During the construction phase of the HVAC commissioning process, the HVAC system is installed, started, and put into operation.

7.1.2 The objectives of the HVAC commissioning process during the construction phase are to

- (a) review submittals;
- (b) finalize details of the Commissioning Plan;
- (c) conduct periodic commissioning team meetings;
- (d) observe construction, installation, start-up, operation, and testing and balancing; and
- (e) conduct O&M training.

7.1.3 During construction of the HVAC system, the O&M personnel should observe and monitor construction of the HVAC systems. They will develop a better understanding of

the system's intended operation and performance and become familiar with the physical installation, particularly the location of equipment and devices, which may be hidden when construction is complete.

7.2 Construction-Phase Procedures

7.2.1 During the construction phase, the following activities shall be assigned:

- (a) preparing design changes,
- (b) reviewing submittals,
- (c) detailing the Commissioning Plan,
- (d) creating project-specific procedures and checklists,
- (e) making necessary observations and inspections,
- (f) updating documentation,
- (g) reporting progress and deficiencies to all parties involved, and
- (h) coordinating training of operations and maintenance personnel.

7.2.2 The Commissioning Plan shall be updated to reflect the installed equipment and system(s), incorporating design changes that occurred during the construction phase. The Commissioning Plan shall also schedule commissioning activities in concert with the overall project schedule, identify the parties to perform the tasks necessary to implement the commissioning specification, and be submitted to the commissioning team.

7.2.3 Observations of the progress of construction are important for updating the Commissioning Plan, particularly with respect to the scheduling of activities. In addition to construction requirements, observations should be conducted to ensure compliance with manufacturers' installation instructions. These observations should include, but not be limited to, the following HVAC subsystems and other interfacing building systems and activities:

- (a) Air-handling and distribution and ventilation systems
- (b) Heating systems
- (c) Cooling systems
- (d) Hydronic systems
- (e) Piping
- (f) Controls
- (g) Building automation systems
- (h) Life safety systems
- (i) Energy supply systems
- (j) Building envelope
- (k) On-site equipment storage
- (l) Indoor air quality methods and procedures
- (m) Compliance with codes and standards
- (n) Witness testing, including flushing, cleaning, pressure testing, and leakage testing

7.2.4 The system operation description shall be updated and combined with equipment data, including performance data, for training of and subsequent use by the operations and maintenance staff. The updated system operation description shall be included as part of the Systems Manual.

7.2.5 Regularly scheduled meetings of the entire commissioning team shall be held for the purpose of site coordination, to communicate issues to all concerned, resolve conflicts,

report on the progress of the HVAC commissioning process, identify urgent work, and identify deficiencies. This is critical to the completion of the commissioning process.

7.2.6 The training program for operations and maintenance personnel shall be coordinated with the appropriate participants. Refer to Clause 11 for details on training procedures.

7.2.7 Observe and document all start-up, testing-adjusting-balancing, and calibration activities.

7.2.8 Controls testing and calibration should begin concurrent with, and be completed prior to, the completion of the testing, adjusting, and balancing work. Some verification procedures as indicated in clause 8 may occur here.

7.2.9 Testing, adjusting, and balancing work must be performed prior to acceptance procedures. Operational tests should also be conducted on equipment, duct, pipe, and control systems to verify that pressures, flow rates, and control functions meet design requirements.

7.3 Submittals

7.3.1 The review of submittals shall be completed prior to construction. Submittals should include shop drawings, equipment submittals, and testing and balancing procedures and forms. Submittals should also include test procedures, report forms, data sheets, and checklists that will be used in the functional performance testing.

7.3.2 Equipment submittals should include complete full- and part-load performance data covering the entire operating range for each piece of equipment, especially heat exchange equipment such as boilers, furnaces, chillers, condensing units, heat exchangers, and coils. Data should include capacity, flow rates, velocity, pressure losses, power, rpm, electrical data, and all other pertinent data as necessary. After review of equipment submittals, the equipment operations and maintenance information (including parts lists, installation instructions, and special tool needs) should be submitted in accordance with specifications requirements.

7.3.3 Given the importance of the control systems to proper operation of the HVAC system, control submittals must be carefully reviewed to ensure they include all information needed by the operations and maintenance staff to keep the control systems adjusted and calibrated. Information should include the following:

- (a) A fully labeled control piping or wiring schematic that shows point-to-point piping and wiring and includes all performance parameters such as setpoints, throttling ranges, actions, spans, proportional bands, and other control component adjustment or setting data. Locations of pneumatic test ports and electronic system terminal strips should be indicated on the schematic drawings.
- (b) Sequence of operation (narrative description of control system functions) cross-referenced to the control schematics and elementary electrical ladder diagrams.
- (c) Specification sheets for each control component, including calibration data.

- (d) Flow charts or other documentation of application software specific to the project.
- (e) Data to confirm interfaces to controlled equipment for compatibility and physical connection requirements.

7.4 Commissioning Plan

The Commissioning Plan shall be updated to define the on-site activities required for implementing the commissioning specifications. This plan must be project-specific and reflect the actual equipment that will be installed. This Commissioning Plan should

- (a) detail the schedule of inspections during construction,
- (b) develop the schedule for verification and functional performance tests,
- (c) define the process for reporting and correcting any deficiencies identified, and
- (d) detail any training sessions for operations and maintenance personnel that are to take place during this phase.

A detailed list of items to be included in this plan is provided in 12.4.1.

7.5 Documentation

7.5.1 All commissioning activities that occur during the construction phase shall be documented, including, but not limited to, those items described in 12.4. The documentation during the construction phase shall be updated to match the equipment supplied on the project.

7.5.2 Appropriate information gathered during the construction phase shall be added to the Systems Manual. Refer to 12.6.

8. ACCEPTANCE PHASE

8.1 Introduction

8.1.1 During the acceptance phase of the HVAC commissioning process, verification, functional performance tests, and other acceptance procedures will take place.

8.1.2 The objectives of the HVAC commissioning process in the acceptance phase are to

- (a) verify the accuracy of the final TAB report,
- (b) verify that the HVAC system complies with the contract documents,
- (c) establish an as-built record of the HVAC system performance,
- (d) complete the as-built records,
- (e) complete the commissioning report,
- (f) complete the Systems Manual, and
- (g) turn over the building to the owner.

8.1.3 Verification will demonstrate the function of the automatic control systems and the accuracy of the final testing, adjusting, and balancing (TAB) report.

8.1.4 Functional performance testing will demonstrate the performance of the HVAC system. The scope of functional performance testing covers the entire HVAC installation, from central equipment for heat and cold generation through distribution of HVAC services to each conditioned space. It

includes measured capacities, effectiveness of operation, and all control functions.

8.1.5 Issues relating to fire, smoke control, and air quality may require the assistance of specialists who are presently outside the process for constructing HVAC systems. Their scope of work must be addressed when it interfaces with the HVAC system and be explicitly included within the HVAC commissioning process.

8.1.6 At the end of the functional performance tests, the documentation should include all of the performance data for the entire HVAC system for each mode of operation.

8.1.7 Conflicts identified during the acceptance phase shall be addressed and resolved to the owner's satisfaction.

8.1.8 Operations and maintenance personnel should be made available to observe all verification and functional performance tests.

8.1.9 At the end of the acceptance procedures, the HVAC system will have been proved and documented to be operational and performing in accordance with the contract documents. This would include all normal operational modes, as well as abnormal or emergency conditions.

8.2 Prerequisites to Acceptance Procedures

8.2.1 Before the acceptance procedures can start, the following shall be observed and documented:

- (a) HVAC systems and associated subsystems have been completed, calibrated, and started up and are believed to be operating in accordance with contract documents.
- (b) Automatic control systems have been completed and calibrated and are believed to be operating in accordance with contract documents.
- (c) Testing, adjusting, and balancing procedures have been completed, and all TAB reports have been submitted and reviewed and discrepancies corrected and accepted.

8.2.2 A statement shall be issued certifying that all work has been completed and equipment and systems are operational in accordance with contract documents.

8.3 Verification

8.3.1 Verification comprises a full range of checks and tests to determine that all components, equipment, systems, and interfaces between systems operate in accordance with contract documents. This includes all operating modes, all interlocks, all control responses, and all specified responses to abnormal or emergency conditions. Verification of the proper operation of the control system also includes verifying the interface of the control system with the TAB criteria and the response of monitoring and control system controllers and sensors. Verification of operating modes, etc., can be done concurrently with controllers and sensors. Verification will also validate the TAB report. Each contractor may have some responsibility to participate in verification. However, the services of an independent testing contractor may be required to perform the tests.

8.3.2 Verification Procedures

8.3.2.1 Operating Tests and Checks. Verification procedures include the following tests and checks.

- (a) All verification procedures will be directed and witnessed and the results certified. The Commissioning Plan identifies responsibilities and details the procedures to be followed.
- (b) The system equipment, e.g., chiller, boiler, HVAC unit, exhaust blowers, will be set into the operating mode to be tested, e.g., normal shut-down, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions.
- (c) Each operating cycle shall be tested after it has been running for a specified period of hours and is operating in a steady-state condition.
- (d) The position of each device and interlock that is identified on the checklist shall be inspected and verified. Each item shall be signed off as acceptable (yes) or failed (no).
- (e) This test will be repeated for each operating cycle that applies to the HVAC system being tested.
- (f) Operating checks shall include all safety cut-outs, alarms, and interlocks with smoke control and life safety systems during all modes of operation of the HVAC system.
- (g) If an operating deficiency is observed during a test, appropriate comments shall be added to the checklist data sheet.
- (h) Verification of the interface of the monitoring and control system and the TAB criteria shall include the following steps:
 1. Verify flow rates for air and water systems in all modes of operation of the HVAC system.
 2. Verify operation of the terminal units in all modes of operation.
 3. Verify minimum outdoor air intake in all modes of operation and at minimum and maximum total airflow rates.
 4. Verify building pressurization.
 5. Verify total exhaust airflow and total outdoor air intake (OAI).
 6. Verify operation of the IAQ monitoring system.

Failure to pass the verification test is as defined in “Verification of Final TAB Report” in 8.3.2.2. The deficiency shall be corrected by the responsible contractor(s) and the condition retested until accepted. Results shall be recorded on the appropriate checklist.

- (i) Verification of the proper response of monitoring and control system controllers and sensors shall include the following steps:
 1. For each controller or sensor, record the indicated monitoring and control system reading and the test instrument reading.
 2. If the initial test indicates that the test reading is outside the control range of the installed device, the calibration of the

installed device shall be checked and adjusted as required. The deficient device shall be retested and the results recorded on the checklist data sheet.

8.3.2.2 Verification of the Final TAB Report. Verification procedures include the following tests and checks:

- (a) The field verification of the final TAB report will be directed and witnessed and the results certified. The Commissioning Plan identifies responsibilities and details the procedures to be followed.
- (b) A random sample of the report data shall be selected for verification. Report data are defined as the air velocity at a specific outlet, air or water flow rate, indicated differential pressure, electrical or sound measurement, or any other measurement that is applicable.
- (c) The testing and balancing contractor shall be given sufficient advance notice of the date of field verification. However, the contractor shall not be informed in advance of the data points to be verified. The testing and balancing contractor must use the same instrument (by model and serial number) that was used when the original data were determined.
- (d) Failure of an item is defined as follows:
 1. For all readings other than sound, a deviation of more than 10%.
 2. For sound pressure readings, a deviation of 3 decibels. Variations in background noise must be considered.
- (e) A failure of more than 10% of the selected items shall result in the failure of acceptance of the final TAB report.
- (f) Failure of the final TAB report shall require the testing and balancing contractor to complete the following work at no additional cost:
 1. Any system failing the verification procedure must be re-balanced.
 2. New total system TAB reports must be provided.
 3. Field verification of the new TAB report must be performed.

8.3.3 Deficiencies. If any deficiencies are identified in the HVAC systems or at the interface with other building systems during verification, the deficiencies must be documented and reported to the commissioning team. A decision must be made whether to remedy the situation and if reverification is required.

8.3.4 Verification Report. The final tabulated checklist data sheets shall be assembled in a verification report and submitted to the commissioning team for review. The verification report shall document any unresolved deficiencies and may suggest a method of correction. The responsible party shall determine if verification is complete and whether the HVAC system is functioning in accordance with the contract documents.

8.4 Certificate of Readiness. A Certificate of Readiness shall be issued stating that all equipment, systems, and controls are now complete and ready for functional performance testing to begin. This certificate shall be supported by completed pre-start / start-up checklists, signed by the responsible parties, and the final verification report.

8.5 Functional Performance Testing

8.5.1 Introduction

8.5.1.1 Functional performance testing should progress from tests of individual components of the central equipment and systems, including chillers, cooling towers, boilers, and pumping systems, to tests of the systems that distribute the HVAC services throughout the building. The extent of these tests, as well as details of the services to be tested, shall be in accordance with the contract documents and the Commissioning Plan.

8.5.1.2 In each of the individual spaces to be tested, the parties performing the functional performance tests may be required to make temporary modifications to control functions or provide supplementary internal loads, such as electric heaters, etc., to simulate desired load conditions up to design load conditions.

8.5.1.3 Functional performance testing of the major heat exchange components may be done at less than full-load capacity of the equipment using part-load performance curves provided by the manufacturer for comparison.

8.5.1.4 As each individual check or test is accomplished, physical responses of the system shall be observed and compared to the specified requirements in order to verify the test results. The actual physical responses of system components must be observed. Reliance on control signals or other indirect indicators is not adequate. The input and output signals for each control component also need to be observed to confirm that they are correct for each physical condition.

8.5.1.5 The specific tests required and the order of testing will vary widely depending on the type and size of system, number of systems, sequence of construction, relationship between building systems, and specific tenant requirements.

8.5.1.6 Perform all functional performance tests specified to confirm that indoor air quality performance meets criteria specified in contract documents. This could include determining the outdoor air ventilation rate, conducting biological and chemical tests, and determining the effectiveness of the distribution of outdoor air to each space. In addition to being included in the final commissioning report, the functional performance tests of air quality procedures may have to be documented separately for submittal to code authorities for review.

8.5.1.7 During functional performance testing of the HVAC system, a failure in performance of a part of the system or of a component may be revealed. Any performance deficiencies must be evaluated to determine the cause and whether they are part of the contractual obligations. After necessary corrective measures are completed, repeat the necessary functional performance tests.

8.5.2 Procedures

8.5.2.1 Functional performance testing will be performed as defined in the commissioning specification and detailed in the Commissioning Plan.

8.5.2.2 For each test, the responsible party will install the measuring instruments and logging devices to record the test data for the required test period. The instrumentation shall meter and record all operating conditions to allow for complete evaluation of the test results.

8.5.2.3 Measurements will be required to allow for calculation of total capacity of the system for each mode of operation under test. These modes of operation include:

- (a) Occupied/unoccupied
- (b) Warm up/cool down
- (c) Economizer cycle
- (d) Emergency power supply
- (e) Life safety/safety systems
 - 1. Smoke control
 - 2. Fire safety
 - 3. Stair pressurization system
- (f) Temporary upset of system operation
- (g) Partial occupancy conditions
- (h) Special cycles

8.5.2.4 For individual room cooling tests, the responsible party shall provide electric room heaters at a schedule of loads defined in the Commissioning Plan.

8.5.3 Deferred Functional Performance Tests

8.5.3.1 If any test cannot be completed because of a deficiency outside the scope of the HVAC system, the deficiency shall be documented and reported to the owner. The deficiencies should be resolved and corrected by the appropriate parties and functional performance tests rescheduled.

8.5.3.2 If the functional performance test plan indicates that specific seasonal testing is to be conducted, the appropriate initial performance tests should be completed and documented and the additional tests scheduled. The parties responsible for the seasonal tests should return to the site to complete and document the tests as scheduled.

8.5.4 Functional Performance Testing Documentation and Reporting Requirements

8.5.4.1 All measured data, data sheets, and a comprehensive summary describing the operation of the HVAC system at the time of the test will be submitted to the commissioning authority.

8.5.4.2 A preliminary functional performance testing report will be prepared and submitted to the design professional. Deviations in performance from contract documents or design intent should be recorded, with a description and analysis included.

8.5.4.3 If it is determined that the HVAC system is constructed in accordance with contract documents and that the performance deficiencies are not covered in the contract documents, a decision must be made as to whether any modifications required to bring the performance of the HVAC system up to the design intent will be implemented or if the functional performance testing will be accepted as submitted. If corrective work is performed, a determination must be made as to

whether a portion of, or all, functional performance testing should be repeated and a revised report submitted.

8.5.4.4 Following a final evaluation of the performance of the HVAC system, the results of this evaluation will be submitted for inclusion in the commissioning report.

8.6 Documentation

8.6.1 Documentation procedures during the acceptance phase include developing documentation from verification and functional performance tests, completing and assembling the final as-built records, and issuing the commissioning report.

8.6.2 Documentation developed during the acceptance phase consists of the following:

- (a) Verification checklist data sheets.
- (b) Verification report.
- (c) Certificate of readiness.
- (d) Functional performance test data records.
- (e) System operation description and final design intent.
- (f) Commissioning Report.

8.6.3 Information to be assembled during the acceptance phase includes the following:

- (a) As-built drawings and other records.
- (b) Final updated operations manuals and maintenance manuals.
- (c) Systems Manual.
- (d) Training documents.

For a more detailed list of documentation, refer to 12.5.

8.7 Final Acceptance

8.7.1 To conclude the acceptance phase, as-built documentation must be compiled, the Commissioning Report and Systems Manual must be completed and submitted, and recommendation for acceptance of the facility determined. It is possible that some acceptance procedures (such as off-season tests) may not have yet been completed, but this should not impede final acceptance.

8.7.2 The Commissioning Report must indicate if the HVAC system has been completed in accordance with the contract documents and if the systems are performing in accordance with the final design intent document.

8.7.3 The Commissioning Report shall identify and discuss any substitutions, compromises, or variances between the final design intent, contract documents, and as-built conditions, and the report may make recommendations for resolution. This report shall be used to evaluate the system and serve as a future reference document during operation of the HVAC system. It shall describe components and performance that exceed design intent and those that do not meet design intent. It may also include a recommendation for acceptance or rejection of the HVAC system.

8.7.4 The completed Systems Manual, operations manuals, maintenance manuals, training records, and other as-built records shall be submitted for review.

8.7.5 Following review, the records specified in 8.7.2 and 8.7.3, along with the recommendation for final acceptance of the HVAC system, shall be submitted to the owner.

9. POST-ACCEPTANCE COMMISSIONING

9.1 Introduction

9.1.1 Post-acceptance commissioning is the continued adjustment, optimization, and modification of the HVAC system to meet specified requirements. It may be utilized on any facility that has previously been commissioned consistent with this guideline. It includes updating documentation to reflect minor setpoint adjustments, system maintenance and calibration, major system modifications, and provision of ongoing training of operations and maintenance personnel.

9.1.2 The objective of post-acceptance commissioning is to maintain the performance of the HVAC system throughout the useful life of the facility in accordance with the current design intent.

9.1.3 The extent of post-acceptance commissioning will be determined by the scope of modifications and occupancy changes that are made in the facility.

9.1.4 Post-acceptance commissioning will start from the base of existing commissioning documentation. This documentation consists of the original commissioning documentation plus any updates from the commissioning of previous modifications.

9.2 Post-Acceptance Commissioning Requirements and Procedures

9.2.1 There are three identifiable levels of post-acceptance commissioning:

- (a) ongoing commissioning activities,
- (b) minor changes or modifications to HVAC systems and changes to occupancy and/or layout, and
- (c) major modifications to facility layout and/or systems.

9.2.1.1 Major modifications will impact overall system characteristics or performance through significant changes in system design or central system capacities. Minor modifications will not anticipate such impacts; they will likely impact individual zones or rooms only.

9.2.1.2 Minor modifications require, as a minimum,

- (a) revision of as-built records, such as final design intent document, Systems Manual, operations manuals, maintenance manuals, and reports;
- (b) testing, adjusting, and balancing of affected systems or sections; and
- (c) training, where operations and maintenance procedures are affected by the modifications.

9.2.1.3 Major modifications require the same efforts, expanded to suit full system commissioning of any HVAC system or subsystem impacted by modifications. Overall system performance must be reestablished. When major modifications are carried out, commissioning procedures in accordance with clauses 5 through 8 should be undertaken, as applicable to the modification.

9.2.1.4 For each level of modification, the impact of planned alterations to the HVAC system must be reviewed to ensure that a comfortable environment and air quality standards for the occupied portions of the facility are maintained.

9.2.2 Ongoing commissioning activities strive to sustain the achieved level of system performance and documentation. To do this requires a proper maintenance program, training and familiarization of new operating staff (refer to clause 11), and related commissioning activities.

9.2.2.1 As equipment and controls are replaced through the maintenance program, calibration and performance should be checked, the necessary documents revised, and any changes or new equipment data sheets included in the Systems Manual.

9.2.2.2 Ongoing training includes refresher training of existing personnel, training of new personnel, and training of all personnel on newly installed equipment or revised operating procedures. It should be consistent with the training provided by the original commissioning process.

9.2.2.3 A standard method of recording complaints received regarding the HVAC system and its operation should be developed and then used consistently. Procedures for responding to complaints should likewise be developed and used.

9.2.2.4 Systems are periodically retested to measure and document their actual performance. System functional performance test (FPT) checklists used in the acceptance phase and subsequent activities should be a guide for retesting. Discrepancies between predicted performance and actual performance and/or an analysis of the complaints received may indicate a need to reevaluate the current design intent or to consider returning to the program phase (clause 5) of the commissioning process.

9.3 Documentation. The final acceptance documentation will be an as-built record of the HVAC system's performance and operation. The Systems Manual will be updated to include any modifications that were made.

10. Commissioning Existing Buildings

10.1 Introduction

10.1.1 If the building was not commissioned during the original construction or if post-acceptance commissioning has not been utilized, a commissioning process, using applicable portions of clauses 5 through 8 of this guideline, should be undertaken to verify or obtain satisfactory HVAC system performance.

10.1.2 Commissioning of HVAC systems in existing buildings consists of first evaluating current system performance and then conducting subsequent actions to achieve, verify, and document desired performance levels.

10.1.3 There are many potential reasons for conducting this evaluation, including the following:

- (a) Previous TAB reports or as-built records are not available or are inaccurate.
- (b) There is a need to establish baseline information prior to conducting modifications.
- (c) Overall system performance has degraded.
- (d) Existing system performance needs to be substantiated.
- (e) Operations and maintenance procedures need to be improved.

- (f) Building performance needs to be audited to reveal system capabilities, such as energy performance and indoor air quality.

10.2 Program for Existing Buildings

10.2.1 The objective of the Program for Existing Buildings is to bring the building HVAC system performance and comfort levels within acceptable parameters and code requirements.

10.2.2 The scope of activities includes a preliminary evaluation, identification of deficiencies, establishing a current design intent, recommending improvements or modifications, and implementation.

10.2.2.1 A preliminary evaluation is a critical and necessary part of commissioning an existing HVAC system. It should not be confused with post-acceptance commissioning. The preliminary evaluation should be considered even if the HVAC system is operating effectively because the system documentation may not be current or even exist, and system modifications may have been made.

10.2.2.2 A preliminary evaluation shall be conducted by a qualified professional.

10.2.2.3 The evaluation shall consist of an audit of the existing facility. Results will be used to modify existing documentation as applicable or to create documentation where it is missing or does not exist. The audit may include the following:

- (a) Review of existing documentation and as-built records.
- (b) Equipment testing.
- (c) Review of operating procedures.
- (d) Review of operating costs.
- (e) Determination of system performance.
- (f) Determination of ventilation effectiveness and air quality.
- (g) Verification of occupant complaints.
- (h) Documentation of the results of all the foregoing items.

10.2.2.4 The preliminary evaluation shall identify deficiencies and develop a recommended program to improve the performance of the HVAC system.

10.2.3 Based upon the preliminary evaluation, the design intent of the proposed building function shall be established.

10.2.4 The recommended program shall be reviewed for conformity with the updated design intent and the items to be implemented shall be defined.

10.2.5 At this point in the commissioning of existing buildings, the process moves to the program phase of this guideline (see 5.3).

11. OPERATIONS AND MAINTENANCE TRAINING PROGRAM

11.1 Introduction

11.1.1 This clause describes the training program for the operations and maintenance (O&M) personnel. The objective of the O&M training program is to provide qualified technicians with the knowledge to operate and maintain the HVAC system in accordance with design intent, manufacturers' rec-

ommendations, and procedures contained in the Systems Manual.

11.1.2 The program shall be detailed such that it can be repeated for new and replacement personnel. Thorough documentation must be supplied for future training activities. Videotaped training sessions may also be used to assist with future training.

11.1.3 Planning and coordinating the training program shall be as defined in the Commissioning Plan. Training shall be performed by parties with specific expertise that relates to each component of the building's HVAC systems.

11.2 Scope of Training

11.2.1 The training program shall furnish a thorough understanding of all equipment, components, systems, and their operation, including appropriate how-to skills. Training shall include the following topics:

- (a) Use of the Systems Manual with an emphasis on
 - 1. design intent;
 - 2. systems description, capabilities, and limitations;
 - 3. system operational procedures for all modes of operation, including warm-up, cool-down, occupied, unoccupied, and others as necessary;
 - 4. acceptable tolerances for system adjustments in all operating modes;
 - 5. procedures for dealing with abnormal conditions and emergency situations for which there is a specified system response;
 - 6. use of the operation manuals; and
 - 7. use of the maintenance manuals.
- (b) Recommended procedures for collecting and interpreting specific performance data.
- (c) Specialized manufacturers' training programs.

11.2.2 The goal of training is a level of understanding of pertinent system performance and the general theory of system and component operation. This level of understanding shall typically include the following:

- (a) Theory of operation
 - 1. Basic concept
 - 2. Energy efficiency
 - 3. Indoor air quality
 - 4. Comfort
 - 5. Occupied vs. unoccupied or partial occupancy
 - 6. Seasonal modes of operation
 - 7. Emergency conditions and procedures
- (b) Types of systems
- (c) System operations
- (d) Operating parameters
- (e) Use of control system
 - 1. Sequence of operation
 - 2. Problem indicators
 - 3. Diagnostics
 - 4. Corrective actions
- (f) Use of reports and logs
- (g) Service, maintenance, diagnostics, and repair

11.2.3 The training program should include classroom activities, hands-on experience, and on-site building system familiarization. Some formalized training may occur in manufacturers' facilities or other technical training centers.

12. COMMISSIONING DOCUMENTATION

12.1 Introduction

12.1.1 Documentation is a critical part of commissioning that cannot be ignored or minimized. The documents will keep all parties informed about what is required, will provide step-by-step guidance for carrying out the commissioning process with maximum efficiency, and will provide a future reference for equipment that was installed in the building and its original performance characteristics. Timely and accurate documentation is essential if the commissioning process is to be effective.

This documentation covers all aspects of planning, design, installation, operation, and maintenance of the systems. It incorporates contract documents, operation manuals, maintenance manuals, and as-built drawings. It includes information listing design criteria, explains system capabilities and limitations, and guides ongoing operational record-keeping and analysis.

The documentation shall contain all data relevant to the systems. Some of the data are necessary archival material, but other material will need to be used by the operator on an ongoing basis and contained in a stand-alone document called the Systems Manual.

The following is a description of the documentation that shall be provided during each phase of a project. If commissioning is not implemented at the program phase, commissioning documentation will need to be developed from existing information.

12.2 Program-Phase Documentation

12.2.1 The Owner's Program, as described in 5.2.1.1, is the document outlining the owner's requirements. It is the critical document that forms the basis from which all other documentation is developed.

12.2.2 As referred to in 5.2.2, the design intent document is a detailed description of the Owner's Program. At a minimum, the design intent document shall include the following information, to the extent possible at each phase of the project.

- (a) Facility's functional use for all hours of the day and night including weekends and holidays.
- (b) Occupancy requirements.
- (c) Quality of material and construction.
- (d) Environmental and air quality requirements.
- (e) Levels of illumination.
- (f) Power distribution capacity and diversity.
- (g) Power quality issues.
- (h) Energy performance criteria
- (i) Description of all operating systems.
- (j) Statement of each system's operation under defined conditions including normal occupancy, partial occupancy, and emergency situations.

- (k) Acceptable performance criteria and operating strategy for each system.
- (l) Defined limits and restrictions for the facility.
- (m) Budget considerations and limitations.

12.2.3 The preliminary Commissioning Plan, referred to in 5.2.3, is a written plan for describing the commissioning process for the HVAC system to meet the owner's requirements and Owner's Program. At a minimum, it should include the following items:

- (a) The initial design intent.
- (b) Time required for completion.
- (c) Staffing, skills, and man-hours required for the process.
- (d) Listing of observations and inspections to be made during construction.
- (e) Listing of the equipment and systems that will be functionally tested.
- (f) Description of documentation.
- (g) Schedule and sequence to provide documentation.
- (h) Acceptance procedures.
- (i) Training requirements.
- (j) Requirements for Systems Manual.

12.2.4 Basis of Design, referred to in 5.2.4, is the formal listing of all information and criteria selected to accomplish the design intent. At a minimum, the Basis of Design should include the following items:

- (a) Indoor dry-bulb temperature for all occupancy conditions.
- (b) Indoor relative humidity for all occupancy conditions.
- (c) Outdoor dry-bulb temperature for each season.
- (d) Outdoor wet-bulb temperature for each season.
- (e) Occupancy, hours, functional use, and degree of activity for all 8,760 hours per year for each activity and/or physical area.
- (f) Lighting power and controls for defined levels of illumination.
- (g) Miscellaneous power for all occupancy and operating conditions.
- (h) Ventilation criteria and effectiveness for all occupancy and operating conditions.
- (i) Special internal loads and other owner requirements.
- (j) R-values for roof, walls, glass, etc.
- (k) Percentage of fenestration.
- (l) Building pressurization and infiltration for all occupancy and operating conditions.
- (m) Maintenance management program.
- (n) Building size, mass, orientation, and characteristics.
- (o) Description of the HVAC system.
- (p) HVAC system's operating pressures and flow rates for normal occupancy and emergency conditions.
- (q) HVAC system control strategies for normal occupancy and emergency conditions, including temperature setpoints.
- (r) Codes, standards, and guideline requirements.

- (s) Air quality criteria.
- (t) HVAC noise and vibration criteria.
- (u) Fire, smoke control, and life safety criteria.
- (v) Energy demand and performance criteria.
- (w) HVAC maintainability.
- (x) HVAC system and equipment quality standards.
- (y) Air cleaning, both particulate and gaseous.

12.3 Design-Phase Documentation. The Commissioning Plan, updated during the design phase, and Commissioning Specification shall cover the following minimum responsibilities and requirements, as applicable:

- (a) Detailed requirements for developing the commissioning specification.
- (b) Requirements for timely delivery of submittals, operations manual and maintenance manual materials, and other documents and the relationship to other functions or payments.
- (c) Detailed description of the organization, layout, and content of documentation.
- (d) Identification of equipment and systems to be commissioned.
- (e) Detailed description of commissioning schedules.
- (f) Detailed identification of what must be completed before the next operation can proceed.
- (g) Detailed description of the responsibilities of each party.
- (h) Detailed description of the methods to be used by each party.
- (i) Detailed description of the observations to be made.
- (j) Detailed description of the submittals that are required to support the commissioning process.
- (k) Detailed description of the documents to be provided along with the identification of the responsible party.
- (l) Detailed description of the verification procedures along with the identification of the parties involved and the responsible party.
- (m) Detailed description of the functional performance test procedures along with the identification of the parties involved and the responsible party.
- (n) Detailed description of the requirements for training of the operations and maintenance personnel, including required manuals.
- (o) Detailed description of the requirements for the Systems Manual.
- (p) Specification of acceptable performance for all equipment, controls, and systems.
- (q) Sample report formats.
- (r) Sample document/manual formats.

12.4 Construction-Phase Documentation

12.4.1 At a minimum, the Commissioning Plan, detailed in the construction phase, shall include:

- (a) Method for documenting changes to appear in as-built records on a continuous basis.

- (b) List of all equipment and systems involved in the commissioning process.
- (c) Pre-start/start-up checklists for all equipment and systems involved in the commissioning process.
- (d) A detailed, step-by-step procedure for conducting the functional performance tests on each piece of equipment and system, with provisions for verifying all relevant data, recording the results obtained, and listing the parties involved in each test.
- (e) Detailed schedule for all commissioning activities, with specific dates consistent with overall project construction schedule.

12.4.2 Reports from site observations shall be submitted with the required information in the agreed-upon format and within the specified time.

12.4.3 Documentation required for the Systems Manual, training manual, and the final commissioning report shall continue to be collected during the construction phase.

12.4.4 Progress reports that keep all parties informed and on schedule are an important part of the commissioning process. They should be distributed promptly and should include information pertinent to the time period covered by that report. Progress reports should cover the following information:

- (a) Activities since the last report.
- (b) Description of changes to the commissioning schedule, Commissioning Plan, and design, along with their effect on the design intent and Basis of Design.
- (c) Listing of equipment and systems not passing verification inspections, functional performance tests, or acceptance tests.
- (d) Listing of items not delivered on schedule.
- (e) Follow-up of all items listed in the previous reports that required action. Such items are to be repeated on subsequent reports until they are resolved.
- (f) Critical items that will occur in the next reporting period.

12.4.5 Training documentation shall include the following items:

- (a) Copy of the training plan, including schedule, syllabus, and agenda.
- (b) Copy of the design intent document.
- (c) Copy of the Basis of Design.
- (d) Specification sheets for each piece of equipment and control.
- (e) Operations manuals.
- (f) Maintenance manuals.
- (g) Manufacturer training manuals.
- (h) Videotape of manufacturer's or vendor's on-site training (optional).
- (i) As-built records.

12.4.6 Operations manuals and maintenance manuals are each a complete collection of all manufacturer's operation and maintenance literature supplemented by information specific to the facility for each piece of equipment, control, and system. Each manual shall be organized into permanently labeled binders

with indexing tab section dividers and a table of contents. The organization, layout, and content shall be as defined in the commissioning specifications. (Refer to *ASHRAE Guideline 4-1993, Preparation of Operating and Maintenance Documentation for Building Systems*.) These manuals form part of the Systems Manual.

Manuals shall include, but not be limited to, the following data:

- (a) Detailed description of each system and each of its components showing piping, valves, controls, and other components, with diagrams and illustrations where applicable.
- (b) Wiring and control diagrams, with data to explain detailed operation and control of each component.
- (c) Control sequences describing start-up, all modes of operation, and shutdown.
- (d) Installation instructions.
- (e) Procedures for starting, operation, and shutdown for every system, including all required emergency instructions and safety precautions.
- (f) Maintenance and overhaul instructions.
- (g) Lubricating schedule including type, grade, temperature, and frequency range.
- (h) Corrected shop drawings.
- (i) Product information identifying all performance curves, rating data, features, options, etc., on all installed equipment.
- (j) Copies of approved certifications and laboratory test reports (where applicable).
- (k) Copies of warranties.
- (l) Test procedures.
- (m) Parts list, including source of supply and recommended spare parts.
- (n) Name, address, and 24-hour telephone number of each subcontractor who installed equipment and systems and local representative for each type of equipment of each system.
- (o) Other pertinent data applicable to the operation and maintenance of particular systems or equipment and/or other data specified in technical sections of the specification.
- (p) Impact of testing and operation of fire and life safety systems on HVAC system.
- (q) Uninterruptible power supplies, including a list of equipment and design kW load on each.
- (r) Emergency power generation, including a list of equipment and design kW load on each.

12.5 Acceptance-Phase Documentation

12.5.1 The final tabulated checklist data sheets shall be assembled in a verification report. The verification report shall document any unresolved deficiencies and may suggest a method of correction.

12.5.2 The Certificate of Readiness is a written document stating that all equipment and systems, including controls, that are involved in the commissioning process have been correctly installed, started as specified, and tested, adjusted, and balanced.

This certificate shall be supported by completed pre-start/start-up checklists signed by the responsible parties.

12.5.3 A signed checklist covering each completed functional performance test shall contain all the identifying information, data, and readings required. The checklist shall be specific for each individual piece of equipment, subsystem, or system. It should include the following information:

- (a) Name and identification code.
- (b) Time and date of the test.
- (c) Individuals present for the functional test.
- (d) Calibration of sensors/sensor function.
- (e) Control sequence.
- (f) Strength of control signal for each setpoint at a defined condition.
- (g) Responses to control signals at a defined condition.
- (h) Sequence of response(s) to control signals at a defined condition.
- (i) Electrical demand or power input at defined conditions.
- (j) Power quality and related measurements.
- (k) Actual flow rates at defined conditions.
- (l) Inlet and outlet temperatures of all fluid streams at defined conditions.
- (m) Inlet and outlet pressures, or pressure drops, of all fluid streams at defined conditions.
- (n) Responses to defined temporary upset of system operation.
- (o) Interaction of auxiliary equipment such as water treatment.
- (p) Trend logs.
- (q) Deficiencies.

12.5.4 Some equipment or systems may fail the functional performance test. The corrective action may require modifications to the equipment or systems or revision to the functional performance test(s). The corrective action must be completed, new functional test(s) performed, and the results documented. Any variance from the defined criteria that is acceptable and requires no modification shall be reported and documented.

12.5.5 The Commissioning Report is the document that summarizes the results of the commissioning process, including conformance to the contract documents and the design intent and as-built system performance. It shall include the following:

- (a) Copy of the design intent document.
- (b) Copy of the Commissioning Plan.
- (c) Copy of verified testing and balancing report.
- (d) List of deficiencies outside the scope of the HVAC system that impact HVAC system performance.
- (e) Copies of all corrective modification documentation.
- (f) Copies of all accepted performance variance documentation.
- (g) Copies of all pre-start/start-up checklists.
- (h) Copies of all completed functional test checklists.
- (i) List of off-season functional performance test(s) not performed and a schedule for their completion.

12.6 Systems Manual

12.6.1 The Systems Manual should provide the information needed to understand, operate, and maintain the systems and/or

to inform others about the systems. It is to be the repository of all updates and corrections as they occur.

12.6.2 The Systems Manual expands the scope of the operating and maintenance documentation developed in ASHRAE Guideline 4-1993 to include the additional information gathered by the commissioning process. Refer to 12.4.6.

12.6.3 The Systems Manual shall include the following:

- (a) Index of all commissioning documents with notation as to their storage location.
- (b) Commissioning Report (refer to 12.5.5).
- (c) Initial and final design intent documents.
- (d) As-built documents.
- (e) Description of systems, including capabilities and limitations.
- (f) Operating procedures for all normal, abnormal, and emergency modes of operation.
- (g) Sequence of operations as actually implemented, with control system data including all setpoints, calibration data, etc.
- (h) Location of all control sensors and test ports.
- (i) Seasonal start-up and shutdown procedures.
- (j) Control schematics and computer graphics.
- (k) Complete terminal interface procedures and capabilities for DDC systems.
- (l) A list of recommended operational recordkeeping procedures including sample forms, trend logs, or others, and a rationale for each.
- (m) Maintenance procedures.

12.7 Post-Acceptance-Phase Documentation

12.7.1 Post-acceptance-phase documentation, referred to in 9.3, will consist of the following:

- (a) Updated as-built documents.
- (b) Maintenance records.
- (c) Modified operating procedures.
- (d) Log of complaints, problems, and corrective actions.
- (e) Log of performance evaluations (equipment and system) at various loads.

12.7.2 As-built documents shall reflect the systems and equipment installed. Control points, test ports, and sensors shall be indicated on the drawings and labeled with the same identifiers used in the control system and on the actual building panels. Ladder diagrams or control flow charts of the actual control sequences/logic shall be included with the as-built documents.

12.7.3 During the first year of operation, all complaints received from the tenants, operations personnel, and maintenance personnel shall be recorded and copies shall be sent to the mechanical contractor and design professional.

12.7.4 Modifications to the systems to accommodate tenant needs shall be recorded in all appropriate documents.

13. REFERENCES

1. ASHRAE. 1991. *ASHRAE Terminology of Heating, Ventilation, Air-Conditioning, & Refrigeration*, Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
2. ASHRAE. 1993. *ASHRAE Guideline 4-1993, Preparation of Operating and Maintenance Documentation for Building Systems*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

(This annex is not part of this guideline but is provided for information purposes only.)

ANNEX A

DISCUSSION OF THE HVAC COMMISSIONING PROCESS

A1. Introduction

ASHRAE Guideline 1-1996 recognizes that the HVAC commissioning process guideline must meet the needs of all building sizes, HVAC systems, and projects. By redefining commissioning as “the process of ensuring systems are designed, installed, functionally tested, and operated in conformity with the design intent” established to meet the owner's needs, it is necessary and advantageous to provide some explanation and detail on the many facets and documents that comprise the process. The guidance and discussion provided is to some extent oriented to new large commercial facilities and the contract-bid construction process. However, the concepts it presents can be used for achieving owners' needs in systems and facilities of all sizes. This guideline and its annexes can be used for HVAC&R system replacement and rehab projects. It can also be used on residential units and for single homes.

It is further recognized that owners of large or multiple buildings (companies, industrial sites, governmental and institutional buildings) may accomplish some or all of the functions described with owner employees. In fact, industrial organizations with major HVAC&R process needs (e.g., clean rooms, photographic products, textile, food, and pharmaceutical) have been some of the major successful users of the commissioning process to achieve desired and successful HVAC&R systems. These owners, when using the commissioning process, will have their own owner representative for the project (may be a project team, including process engineers), select a commissioning authority from within their organization, assign a design team, and select the in-house construction group. The system operations and maintenance organization will frequently be within the construction group. In many cases, selected tasks are contracted for a specific project, including the commissioning authority, design team, construction manager, contractors, or even the O&M services. Frequently, the owner's representative will be the construction manager.

Homeowners can use the concepts of the commissioning process to achieve individual comfort desires and energy efficiency without increasing total construction costs. The architect or residential contractor can use cost trade-offs (e.g., envelope, ductwork, structural design) to cover the cost of better controls and more efficient equipment. The commissioning process allows this to occur, since it formalizes the homeowner's needs and requires full consideration of design intent, including temperature and humidity control, special exhaust requirements, energy operating costs, and system maintenance and servicing requirements and costs.

Most information in this annex may be too detailed for small projects (e.g., small commercial buildings and residential HVAC systems, replacement of components) and not sufficient for complex buildings or industrial HVAC systems that support manufacturing or processes. The discussion and sample documents provided can assist everyone in achieving successful HVAC projects using the commissioning process. They are included to assist all owners in developing their own required service documents, but, since examples cannot be developed to match the needs of all commissioning projects, they are therefore not part of the essential requirements of this guideline.

A2. Responsibilities of the Participants in a Sample Comprehensive Commissioning Process

Understanding and defining the role of each participant is vital to the success of the commissioning process. This section provides an example of the responsibilities of each participant in a comprehensive HVAC commissioning process. The responsibilities of each participant should be included in the appropriate section of the contract documents as follows (*Construction Specification Institute [CSI] divisions and sections are provided for reference*):

Commissioning authority - Section 15995, part 1.2.C Responsibilities

Construction manager - Division 1, Section 01440

Mechanical contractor - Section 15010, Mechanical General Provisions

Testing, adjusting, and balancing contractor - Division 15, Test, Adjust, and Balance

Electrical contractor - Section 16010, Electrical General Provisions

Automatic controls and building automation system contractors - Section 15900, Automatic Controls

Testing contractor, appropriate specialists - Division 15 or 16

Equipment suppliers and miscellaneous contractors - Appropriate Division 15 section

The responsibilities of the architect, mechanical and electrical design professionals, or any other design professionals associated with the HVAC commissioning process should be clearly stated in the request for design services and as appropriate in the project specifications. Responsibilities of the commissioning authority should be clearly stated in the request for commissioning services, and as appropriate in the contract documents.

The responsibilities of the following participants-owner, commissioning authority, architect, HVAC design professional, electrical design professional, construction manager, mechanical contractor, TAB contractor, automatic controls and building automation system contractors, electrical contractor, testing contractor, and equipment suppliers and miscellaneous contractors-are detailed below for this example. Note that a participant may fill more than one role (e.g., the

design professional may also be the commissioning authority). The testing contractor may be in the commissioning authority's organization, or an independent contractor, or the TAB contractor, supervised and directed by the commissioning authority.

Owner

1. Include a statement regarding architect/engineer commissioning responsibilities in request for design services.
2. Develop and commit to the Owner's Program for the facility and its use.
3. Assign operations and maintenance personnel and schedule them to participate in the various meetings, training sessions, and observations/inspections as follows:
 - a. Construction-phase coordination meeting.
 - b. Initial owner training session at initial placement of major equipment.
 - c. Maintenance orientation and inspection.
 - d. Piping and ductwork test and flushing verification meetings.
 - e. Procedures meeting for testing, adjusting, and balancing.
 - f. Owner's training session.
 - g. Verification demonstrations.
 - h. Functional performance tests.
 - i. Final review at acceptance meeting.
4. Review and approve any changes made to design intent.
5. Review and approve the construction documents.
6. Provide qualified personnel for videotaping and editing of training sessions.
7. Videotape construction progress.
8. Review and comment on the commissioning authority's verification report.
9. Review and accept the commissioning authority's commissioning report.

Commissioning Authority

1. Organize and lead the commissioning team.
2. Prepare the initial design intent document from the information contained in the Owner's Program.
3. Prepare a program-phase Commissioning Plan that describes in general the extent of the commissioning process to accomplish the Owner's Program and the initial design intent.
4. Develop the design-phase Commissioning Plan, which details the extent and activities of the commissioning process including commissioning team organization, schedule, training, and documentation requirements and all related testing, verification, and quality control procedures.
5. Review and comment on the impact of the design documents on the HVAC commissioning process for the mechanical, electrical, structural, plumbing, process, interior design, and other design professionals within the commissioning process, so that interfaces between systems are recognized and coordinated.
6. Prepare the construction-phase HVAC Commissioning

Plan required as part of the commissioning specification. Include list of all contractors for commissioning events by name, firm, and trade specialty.

7. Execute the HVAC commissioning process through organization of all meetings, tests, demonstrations, training events, and performance verifications described in the contract documents and approved HVAC commissioning process. Organizational responsibilities include preparation of agendas, attendance lists, arrangements for facilities, and timely notification to participants for each commissioning events. The commissioning authority shall act as chair at all commissioning events and ensure execution of all agenda items. The commissioning authority shall prepare minutes of every commissioning event and send copies to all commissioning team members and attendees within five workdays of the event.
8. Review the plans and specifications with respect to their completeness in all areas relating to the HVAC commissioning process. This includes ensuring that the design phase Commissioning Plan has been followed and that there are adequate devices included in the design to ensure the ability to properly test, balance, and adjust the systems and to document the performance of each piece of equipment and each system. Any items required but not shown shall be brought to the attention of the construction manager prior to submittal of shop drawings.
9. Schedule the construction-phase coordination meeting within 90 days of the award of the contract at some convenient location and at a time suitable to the construction manager, the HVAC design professional, and the electrical design professional. This meeting will be for the purpose of reviewing the complete HVAC commissioning process and establishing tentative schedules for mechanical and electrical system orientation and inspections; O&M submittals; training sessions; system flushing and testing; job completion; testing, adjusting, and balancing (TAB) work; and functional performance testing.
10. Schedule the initial owner HVAC training session so that it will be held immediately before the mechanical system orientation and inspection. This session will be attended by the owner's O&M personnel, the HVAC design professional, the electrical design professional, the mechanical contractor, the electrical contractor, and the commissioning authority. The HVAC design professional will conduct this session with assistance from the electrical design professional, giving an overview of the system, the system design goals, and the reasoning behind the selection of the equipment.
11. Coordinate the HVAC mechanical system orientation and inspection following the initial training session. The mechanical system orientation and inspection will be conducted by the mechanical contractor. The emphasis of this orientation and inspection will be an observation of the equipment location with respect to accessibility. Prepare minutes of this meeting, with separate summaries of deficiency findings by the owner's staff and commissioning authority. Distribute to attendees and the owner.

12. Coordinate the HVAC electrical system orientation and inspection following the HVAC mechanical system orientation and inspection session. The electrical system orientation and inspection will be conducted by the electrical contractor. The emphasis of this orientation and inspection will be an observation of the equipment location with respect to accessibility and function. Prepare minutes of this meeting, with separate summaries of deficiency findings by the owner and commissioning authority. Distribute to attendees and the owner.
13. Receive and review the operations and maintenance (O&M) manuals as submitted by the contractor. Ensure that they follow the specified outline and format. Insert systems description as provided by the HVAC design professional in the Systems Manual.
14. Check installation for adequate accessibility for maintenance and component replacement or repair.
15. Witness equipment, subsystem, and system start-up and testing. Ensure the results are documented, including a summary of deficiencies, and incorporated in the O&M manuals.
16. Prior to initiating the TAB work, meet with the owner, mechanical contractor, HVAC design professional, and TAB contractor. The TAB contractor will outline TAB procedures and get concurrence from the HVAC design professional and commissioning authority. Ensure that the TAB contractor has all forms required for proper data collection and understands their importance and use.
17. Schedule the O&M training sessions. These training sessions are to be attended by the owner, the commissioning authority, the HVAC design professional, the electrical design professional, the construction manager, contractors, and equipment suppliers as necessary. The format will follow the outline in the O&M manuals. They should include hands-on training.
18. Upon receipt of notification from the construction manager that the HVAC system has been completed and is operational and the TAB report has been accepted by the HVAC design professional, proceed to verify the TAB report and the function of the control systems in accordance with the commissioning specification. Prepare a verification report, including all test data and identification of any deficiencies, and submit it to the owner and HVAC design professional for review.
19. Supervise the commissioning team members in the functional performance tests. The test data will be part of the commissioning report.
20. Review as-built drawings for accuracy with respect to the installed systems. Request revisions to achieve accuracy.
21. Ensure that the O&M manuals and all other as-built records have been updated to include all modifications made during the construction phase.
22. Prepare the Systems Manual.
23. Repeat functional performance tests to accommodate seasonal tests and/or correct any performance deficiencies. Revise and resubmit the Commissioning Report.
24. Prepare the final Commissioning Report.
25. Assemble the final documentation, which will include the Commissioning Report, the Systems Manual, and all as-built records. Submit this documentation to the owner for review and acceptance.
26. Recommend acceptance of the HVAC system to the owner.

Architect

1. Provide adequate support to the design professionals who must provide a service as a part of the commissioning process. This includes providing information to produce the basis of design and adequate space for equipment installation and maintenance.
2. Include a statement regarding commissioning in Division 1 - General Requirements, alerting all parties to the need to participate.
3. Select construction and finish materials that minimize adverse effects on indoor air quality (IAQ).

HVAC Design Professional

1. Provide documentation of basis of design and initial design concepts.
2. Provide HVAC system design parameters and revisions to the initial design intent document as necessary, obtaining approval of the owner.
3. Prepare contract documents, including the commissioning specification and description of the HVAC system.
4. Prepare contract documents that coordinate interfaces between life safety systems and HVAC systems, including commissioning specifications.
5. Attend construction-phase coordination meeting to be scheduled by the commissioning authority within 90 days of the award of contract.
6. Specify and verify adequate maintenance accessibility for each piece of equipment in shop drawings and actual installation. Periodic inspections are part of the HVAC design professional's construction administration duties.
7. Develop an overview of system design and operation concepts for the Systems Manual.
8. Conduct the HVAC training session on the overview of the system design, the system design goals, and the reasoning behind the selection of equipment. Provide detailed training for complex installations.
9. Participate in O&M personnel orientation, inspection, and training at the final construction stage.
10. Review TAB procedures submitted by TAB contractor.
11. Attend initial meeting with TAB contractor scheduled by commissioning authority.
12. Attend the classroom portion of the owner training sessions. Attendance at the hands-on demonstration is optional.
13. Review verification and functional performance testing procedures submitted by the testing contractor.
14. Review TAB report and verification data sheets for system conformance to contract documents. Issue a report noting deficiencies requiring correction to the construction manager. Review and accept the final TAB report.

15. Review verification data sheets for system conformance to contract documents. Issue a report noting deficiencies requiring correction to the construction manager.
16. Review and comment on the commissioning authority's verification report. Issue a report, if necessary, noting any additional deficiencies requiring correction to the construction manager. Once satisfied with the completion of verification, issue the Certificate of Readiness allowing functional performance testing to begin.
17. Review testing contractor's functional performance testing report for system conformance to contract documents. Issue a report noting deficiencies requiring correction to the construction manager. Review testing contractor's functional performance testing report for deficiencies in meeting the finalized design intent. Issue a report noting deficiencies to the owner.
18. Review and accept as-built records as required by contract documents and turn them over to the commissioning authority.
19. Review and comment on the final commissioning documentation.
20. Be responsible for system evaluation, adequacy of the system to meet design intent, capacity of the system, quality control checks, or any of the other elements of the system design and recommend final acceptance of the HVAC system to the owner.

Electrical Design Professional

1. Provide documentation or design narratives for electrical services to be provided for specific mechanical equipment requirements. This information should be included in the Systems Manual.
2. Provide electrical system information confirming compatibility with electrical service requirements specified by the mechanical design professional for all HVAC equipment and systems. Provide information necessary for the basis of design.
3. Prepare contract documents that coordinate interfaces between life safety systems and HVAC systems including commissioning specifications.
4. Attend construction-phase coordination meeting scheduled by the commissioning authority.
5. Participate in the start-up of HVAC equipment and systems.
6. Participate in the HVAC training sessions as required.
7. Participate in review of shop drawings for mechanical equipment.
8. Prepare electrical ladder wiring diagrams indicating power source connections to HVAC equipment and systems and interrelationships between life safety systems and HVAC systems and equipment, including a review of the automatic control and/or building automation system.
9. Prepare as-built electrical service record drawings as required by contract documents.
10. Verify that any space requirements for electrical equipment are in accordance with relevant code requirements.
11. Participate in O&M personnel orientation and inspection sessions.

Construction Manager

1. Include costs for commissioning requirements in the contract price.
2. Include commissioning requirements in all contractors' contracts to ensure full cooperation of all parties in the HVAC commissioning process.
3. Provide adequate accessibility to all installed HVAC equipment for maintenance and component replacement or repair.
4. Ensure acceptable representation with the means and authority to prepare and coordinate execution of the HVAC commissioning process as described in the contract documents.
5. Issue a statement that certifies all work has been completed, including control systems calibrated and operational, in accordance with contract documents.
6. Issue a statement that TAB work has been completed, and submit the final TAB reports to the HVAC design professional for review and acceptance.
7. Remedy deficiencies identified in verification tests.
8. Evaluate any performance deficiencies identified in the FPT report for nonconformance with construction documents.
9. Review final commissioning documentation.

Mechanical Contractor

1. Include costs for commissioning requirements in the contract price.
2. Include requirements for submittal data, O&M data, and O&M training in each purchase order or subcontract written.
3. Ensure cooperation and participation of specialty subcontractors, such as sheet metal, piping, refrigeration, water treatment, TAB, and controls contractors.
4. Ensure coordination, installation, and operation of interfaces between life safety and HVAC systems.
5. Ensure participation of major equipment manufacturers in appropriate training and testing activities.
6. Attend construction-phase coordination meeting scheduled by the commissioning authority. Prepare necessary preliminary schedule for mechanical system orientation and inspections, O&M manual submission, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, TAB, and task completion for use by the commissioning authority. Update schedule as appropriate throughout the construction period.
7. Attend initial training session, and conduct mechanical system orientation and inspection at the equipment placement completion stage. Update drawings to record condition to date, and review with the commissioning authority.
8. Gather O&M data on all equipment and assemble in binders as required by the commissioning specification. Submit to commissioning authority prior to the completion of construction.
9. Notify the commissioning authority when equipment and system start-up and testing can be witnessed.

10. Notify the commissioning authority of the time for start of the TAB work. Attend the initial TAB meeting for review of the TAB procedures.
 11. Participate in, and schedule equipment suppliers and contractors to participate in, the training sessions as set up by the commissioning authority.
 12. Conduct a mechanical system orientation and inspection with hands-on training. Update drawings to record condition to date, and review with the commissioning authority prior to the orientation.
 13. Provide written notification to the construction manager and commissioning authority that the following work has been completed in accordance with the contract documents and that the equipment, systems, and subsystems are functioning as required.
 - a. HVAC equipment, including all fans, air-handling units, dehumidification units, ductwork, dampers, terminals, and all Division 15 equipment.
 - b. Refrigeration equipment, pumping systems, and heat rejection equipment.
 - c. Boilers, pumping systems, and fuel supply systems.
 - d. Fire stopping in the fire-rated construction, including fire and smoke damper installation, caulking, gasketing, and sealing of smoke barriers.
 - e. Dedicated smoke control systems, including stairway pressurization and atrium systems.
 - f. Nondedicated systems using the air-handling units for smoke control.
 - g. Fire detection and smoke detection devices furnished under other divisions of this specification as they affect the operation of the smoke control systems.
 - h. That building control systems are functioning to control HVAC equipment and smoke control systems.
 14. Demonstrate the operation of each piece of equipment to the commissioning authority. Schedule subcontractors as may apply to demonstrate the operation of the equipment and systems.
 15. Provide services of an engineer to participate in verification tests.
 16. Turn over set of as-built records to the commissioning authority.
6. At the completion of the TAB work and submittal of final TAB report, notify the mechanical contractor and demonstrate to the commissioning authority the performance of the equipment covered by the TAB contract as detailed in the commissioning specification.
 7. Participate in verification of the TAB report and repeat any measurement contained in the TAB report where required by the commissioning authority for verification or diagnostic purposes.

Automatic Controls and Building Automation System Contractors

1. Include costs for commissioning requirements in the contract price.
2. Provide submittals, as-built documents, and appropriate O&M manual section(s).
3. Attend commissioning coordination meetings scheduled by the commissioning authority as appropriate.
4. Participate in training sessions as scheduled by the commissioning authority.
5. At the completion of automatic controls and building automation systems' start-adjustment work, notify the mechanical contractor and demonstrate the performance of the automatic controls and building automation systems to the commissioning authority.
6. Provide services of a controls engineer to participate in verification tests and FPT.

Electrical Contractor

1. Include costs for commissioning requirements in the contract price.
2. Include requirements for submittal data, O&M data, and O&M training in each purchase order or subcontract written.
3. Enlist the support of the construction manager to ensure cooperation of other subcontractors such as the automatic controls and building automation systems contractor, fire detection, and security as necessary.
4. Ensure participation of major equipment manufacturers through their representatives.
5. Ensure coordination, installation, and operation interfaces between life safety and HVAC systems.
6. Attend construction-phase coordination meeting scheduled by the commissioning authority. Prepare necessary preliminary schedule for O&M personnel orientation and inspections, O&M manual submission, training sessions, equipment start-up, testing and adjusting, and job completion for use by the commissioning authority. Update schedule as appropriate throughout the construction period.
7. Attend initial training session and conduct the electrical system orientation and inspection at the equipment placement completion stage. Update drawings to record condition to date, and review with the commissioning authority.
8. Gather O&M data on all equipment and assemble in binders as required by the commissioning specification. Submit to commissioning authority prior to the completion of construction.

Testing, Adjusting, and Balancing Contractor

1. Include costs for commissioning requirements in the contract price.
2. Attend initial commissioning coordination meeting scheduled by the commissioning authority.
3. Submit the TAB procedures for review and acceptance by the HVAC design professional.
4. Attend the TAB review meeting scheduled by the commissioning authority. Be prepared to discuss the TAB procedures that will be followed in testing, adjusting, and balancing the HVAC system.
5. Participate in training sessions as scheduled by the commissioning authority.

9. Notify the commissioning authority of the time for each required test.
10. Participate in and schedule equipment suppliers and contractors to participate in the training sessions as set up by the commissioning authority.
11. Conduct a maintenance orientation and inspection with hands-on training. Update drawings to record condition to date and review with the commissioning authority prior to the orientation.
12. Provide written certification to the construction manager and the commissioning authority that the work has been completed in accordance with the plans and specifications and that it is functioning as designed. Where the work has been subcontracted, the contractor shall be responsible for the initial certification, with the electrical contractor certifying that he/she has inspected the work and that it has been completed and is functioning as designed. This certification must be submitted to the commissioning authority prior to the final verification.
13. Demonstrate the operation of each piece of equipment to the commissioning authority. Schedule subcontractors as they apply to demonstrate the operation of the equipment and systems.
14. Turn over set of record mark-up drawings to the electrical design professional for final incorporation into record documents.

Testing Contractor

1. Provide services of an experienced testing technician.
2. Provide detailed checklist data sheets to document verification tests.
3. Submit detailed verification test procedures and data sheets for review by the HVAC design professional.
4. Submit detailed FPT procedures for review and acceptance by the commissioning authority.
5. Submit detailed list of test instrumentation with appropriate calibration records to be utilized for verification and FPT. Record data as necessary.
6. Conduct verification tests.
7. Submit verification test data to the HVAC design professional and commissioning authority for review.
8. Conduct FPT, including opposite season tests, as required.
9. Submit FPT report to the commissioning authority for review and acceptance.
10. Retest if performance deficiencies are found and corrected and additional testing is requested.

Equipment Suppliers and Miscellaneous Contractors

1. Include costs for commissioning requirements in the contract price.
2. Provide submittals and appropriate O&M manual section(s).
3. Attend initial commissioning coordination meeting scheduled by the commissioning authority.
4. Participate in training sessions as scheduled by the commissioning authority.

5. Demonstrate operation and performance of equipment as applicable.

A3. Sample Comprehensive HVAC Commissioning Process Flow Chart and Organizational Structure

A3.1 Introduction

The flow chart and organizational structure shown here depict an example of the comprehensive commissioning process that starts with the owner's need to build a new facility or renovate an existing one and continues through the acceptance of the HVAC system to post-acceptance. The commissioning process should continue through the life of the facility.

Possible variations in the implementation of the commissioning process include the following:

- 1) The owner may decide to start a commissioning process at some later point in the development of the facility. For example, the commissioning authority may not become involved until the construction documents are completed. In this situation, earlier steps appearing in the flow chart, i.e., preliminary and updated Commissioning Plans, become part of the HVAC design professional's responsibilities along with preparation of the commissioning specification. Once the commissioning authority is under contract, the authority's responsibilities would follow the remainder of the flow chart and include review of the owner's earlier selected commissioning activities.
- 2) For a project where the owner chooses to have the project developed and constructed under a design-build contract, the functions of the HVAC design professional, and construction manager are combined within one organization. In this case, the role of the commissioning authority would follow the owner's requirements as in a typical construction process.

A4. Example Request for Commissioning Services

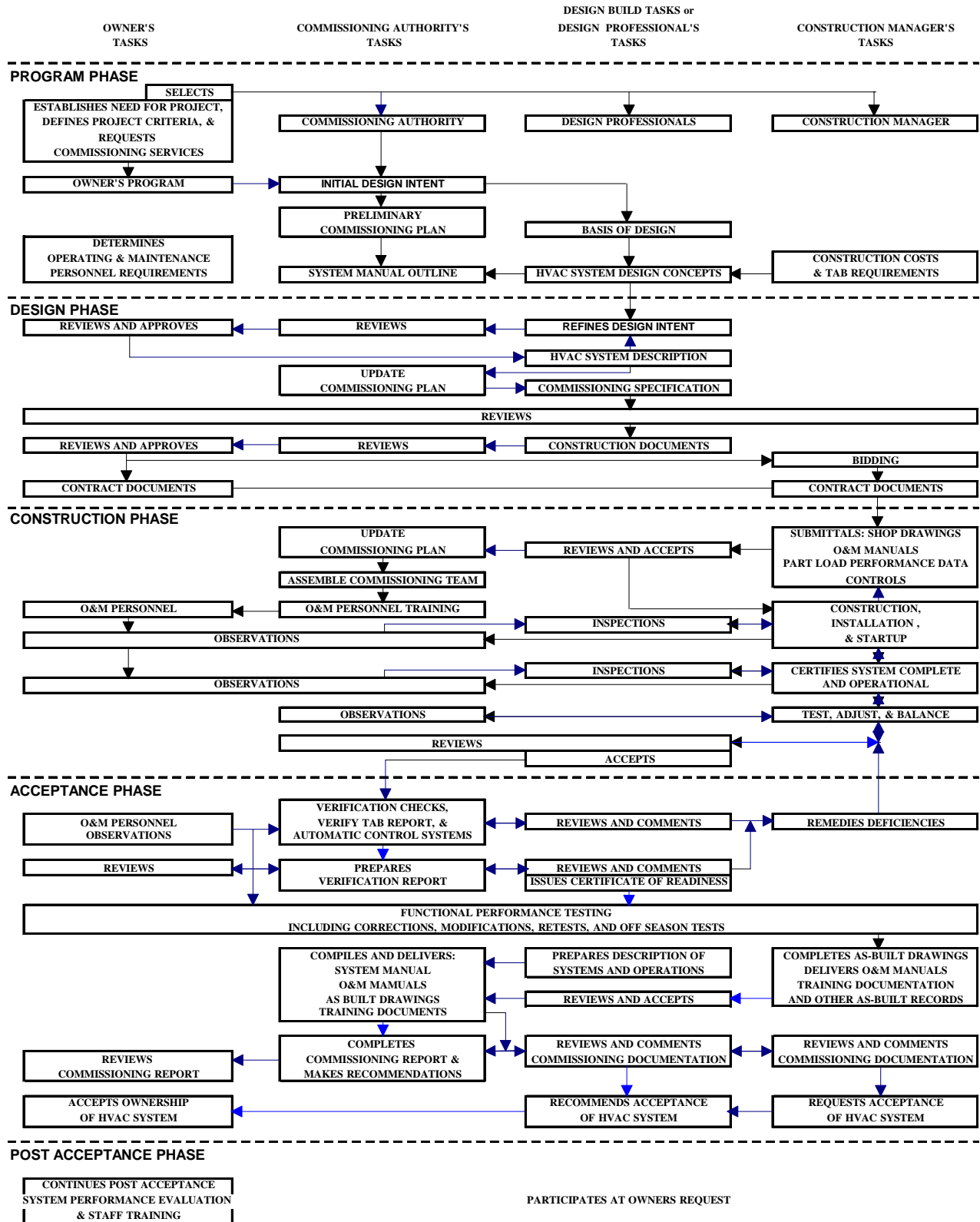
A4.1 Overview

The Request for Commissioning Services is a document owners can use to initiate commissioning services for the project. Its use is suggested to meet the quality and economic goals of this guideline. It is applicable to owners undertaking in-house projects, design-build projects, and typical specification-bid-contract construction projects.

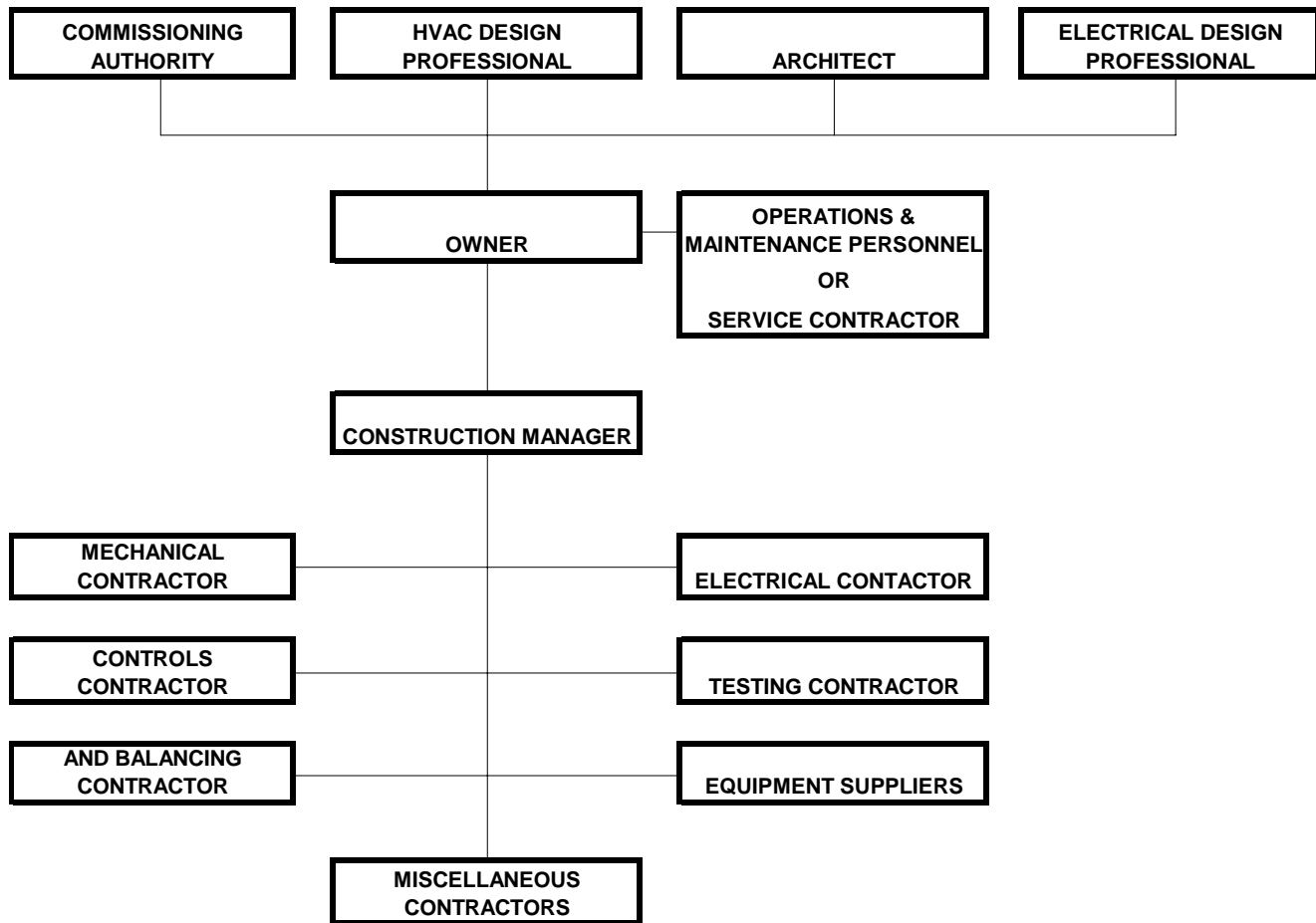
The example has been written to give the owner guidance in providing typical information describing the services or scope of work of the commissioning authority. It is provided to enhance the diverse use of the ASHRAE commissioning process. It applies both to solicited independent commissioning authorities and the owner's employees performing the role of commissioning authority.

This example contains two parts. It suggests the basic or minimum requirements for describing the scope of work of the commissioning authority. It also includes, in italics, additional information that in many cases may be provided to achieve specific needs or to explain or expand the example.

A3.2 A Comprehensive HVAC Commissioning Process Flow Chart



A3.3 HVAC Commissioning Process Organizational Structure



A4.2 Example

Success + Plus Request for Commissioning Services
(Success + Plus is a fictitious name.)

A. PROJECT DESCRIPTION AND PURPOSE

Success + Plus (*owner*) is requesting commissioning services for an HVAC system serving a 60,000 ft² (5,574 m²), five-story office facility. An energy-efficient building is desired. The facility will have an energy management control system. The facility will contain conditioned office space along with retail space and possibly a restaurant on the main floor. Remaining floors will be utilized as general lease space and may include law and financial services and medical and dental suites as highlighted on the attached sketch (*figurative - no attachment*). The facility is to operate with extended retail hours, and general lease space must accommodate after-hours and weekend work.

The building will be located as described on the attached site plan (*figurative - no attachment*).

A description of this type would be sufficient for an owner who does not have the background or experience to select the most effective and most economical system for the facility. The site plan referred to above should be as detailed as possible at this preliminary stage. It may be as simple as a survey plot with estimated building dimensions drawn in. For

other owners, a preliminary description of an HVAC system would be included in this section. An example of such a description follows.

The HVAC system will be designed by an engineering design firm. The HVAC system will consist of a water-cooled chilled-water system with one air-handling unit per floor. The air distribution system will consist of six to eight VAV terminal units per floor, with heating service at each terminal. The facility will have a building automation system in conjunction with an energy management control system (EMCS). Control type will be direct digital control (DDC) with the operator's terminal located in the facility manager's office.

B. SCOPE OF COMMISSIONING SERVICES

Commissioning services ensure the successful design, installation, and performance of the proposed system.

Commissioning services will include:

- Documenting the owner's requirements.
- Developing initial design intent with the owner.
- Developing specific Commissioning Plans as the project progresses.
- Proposing scheduling requirements.
- Assisting the design professional in
 - 1) developing the commissioning specification,

- 2) reviewing the design documents as they are prepared,
 - 3) reviewing shop drawings and equipment submittals for information affecting the commissioning process,
 - 4) developing acceptance procedures,
 - 5) developing training requirements,
 - 6) developing a preliminary Systems Manual.
- Organizing and leading the commissioning team.
 - Developing a schedule for construction and acceptance phase commissioning activities and coordinating it with the overall project schedule.
 - Performing on-site observations during construction.
 - Supervising the acceptance tests, including verification and functional performance tests.
 - Organizing and directing the training of O&M personnel.
 - Preparing the final Systems Manual.
 - Preparing and submitting a commissioning report.
 - Organizing the final as-built records.
 - Providing follow-up for quality performance during guarantee period.

Success + Plus may choose to expand the scope of commissioning services to include the following:

- Assisting in selection of the architect and engineering design team.
- Conducting acceptance and functional testing.

C. QUALIFICATIONS

The qualifications for selecting a commissioning authority will depend on the type of facility to be built and the occupancy it will be designed to serve.

As a minimum, the qualifications include the following:

- Minimum five years of construction experience.
- Experience or training with the ASHRAE commissioning process.
- Controls and instrumentation experience.
- Knowledge and experience with specific types of buildings and HVAC systems.
- Excellent oral and written communication skills.
- Experience working with multidiscipline teams.

The following additional qualifications could be considered for specific HVAC systems:

- Minimum of ten years of design experience.
- Operation and maintenance experience.
- Familiarity with testing, adjusting, and balancing.
- Knowledge and experience with life safety codes and procedures.
- Professional registration.

D. SUBMITTAL REQUIREMENTS

A statement of qualifications, as identified above, shall be submitted. From the information received, a short list of applicants will be selected.

Potential candidates may be requested to attend an interview and provide a sample of written work, including a copy of a Systems Manual and a commissioning report from a previous job and a list of previous clients.

E. TERMS AND CONDITIONS

The selected applicant shall provide a quote for commissioning services on a lump sum [hourly] basis and as a stand-alone service.

The terms and conditions are often “canned” documents prepared by the owner’s organization for purchasing outside services.

F. SCHEDULE

Development of the design intent document and Commissioning Plan shall be completed by *(insert date)*. Preliminary design documents will be provided for review during *(provide time period)*.

Construction is planned to begin by *(insert date)* and planned to end in *(insert time period)*.

An estimated project schedule should be supplied so the applicants for commissioning services will understand any special time constraints at the time of proposal submission.

Proposals are due by *(insert date)*.

A5. Sample Preliminary Commissioning Plan

This sample preliminary Commissioning Plan has been developed by Do It Right Associates (fictitious name) during the program phase for Success + Plus (fictitious name).

Success + Plus has selected Do-it-Right Associates as the Commissioning Authority. The experience of Do-It-Right Associates (D-I-R) has been that HVAC installations invariably develop one or more performance problems related to the understanding of design intent, installation, and operation. These problems could easily be prevented or resolved through a coordinated commissioning process, a formal, planned approach that includes planning, design, construction, start-up, and operations. Success + Plus intends to use commissioning to ensure that the design meets their functional needs and that all system components work together in the manner intended in the design.

PART 1—GENERAL

Definition

Commissioning is the process of ensuring systems are designed, installed, functionally tested, and operated in conformance with the design intent. Commissioning begins with planning and includes design, construction, start-up, acceptance, and training and can be applied throughout the life of the building. Furthermore, the commissioning process encompasses and coordinates the traditionally separate functions of system documentation, equipment start-up, control system calibration, testing and balancing, and performance testing.

Commissioning Team

The commissioning team shall be made up of representatives from Success + Plus, the commissioning authority, the architect, the HVAC design professional, the electrical design professional, major equipment suppliers, mechanical trades, and other trades as appropriate. The lead tradesman for each trade who will actually perform or supervise the work is to be designated as the representative to the commissioning team. Responsibility for various steps of the commissioning process will be accomplished by the commissioning team member, as described in this plan.

Commissioning Authority

As the commissioning authority, Do-It-Right Associates will have responsibility for coordinating and directing each step of the commissioning process and for recommending acceptance or non-acceptance to Success + Plus.

Do-It-Right Associates
241 Intent Street
Commissioning, Prospect Land
800-COM-AUTH

Initial Design Intent

During the program phase, D-I-R shall develop the initial design intent working with Success + Plus. The initial design intent will describe the functional needs, intended levels and quality of environmental control, and environmental needs. The description shall include criteria for each separate component as well as whole systems. This description will be referred to in case of ambiguities or uncertainties about the design intent.

Once developed, the initial design intent will be turned over to the design professionals as a reference document from which the design professional can develop the basis of design. Changes to the initial design intent occurring during the design and construction phase will be documented by the design professional, and will be reviewed by D-I-R and approved by Success + Plus. The design intent will become part of the construction documents. The final design intent document, updated to reflect as-built conditions, shall become a part of the Systems Manual.

PART 2—CRITERIA FOR SELECTION OF DESIGN PROFESSIONALS AND CONSTRUCTION MANAGERS

Do-It-Right Associates shall define special criteria for this project that will assist in the selection of design professionals and contractors. Experience and knowledge of the commissioning process will be considered in the selection of architects, engineers, and contractors.

PART 3—COMMISSIONING PROCESS

Commissioning Specification

During the program phase D-I-R will identify the commissioning specification needs and format for the construction documents in an expanded Commissioning Plan. During

this phase an outline for the commissioning specification will be developed listing organizational matters, management responsibilities, responsibilities of commissioning team members, specification of functional performance testing requirements, specification of acceptance test procedure requirements, documentation requirements, and O&M personnel training requirements. Success + Plus should be aware that O&M personnel need to be selected early in the process to observe construction and participate in training as the construction proceeds.

A6. Commissioning Specification

A6.1. Overview

The commissioning specification is a detailed description of the scope and objective of the construction, acceptance, and post-acceptance phases of the HVAC commissioning process. It is required to contractually implement the post-design phases of the process. It must be project specific, founded upon the Owner's Program developed in the program phase and utilizing the design-phase Commissioning Plan provided by the commissioning authority. Producing the commissioning specification is typically the responsibility of the design professional.

The information developed in the Owner's Program will form the introductory summary of the commissioning specification. This summary should indicate the purpose for implementing the process and the roles of all participants involved. If the program and design phases are not executed and the Owner's Program and design-phase Commissioning Plan are not available, the owner must provide a description of the scope, objective, and organizational structure desired to implement the remainder of the process.

The body of the commissioning specification must detail the scope of work, roles, responsibilities, and requirements of the commissioning team, allowing each participant to prepare bids as necessary for the services required to fully execute his or her part of the process. The commissioning team may include the owner, the project manager, the operations and maintenance personnel, the design professional(s), the mechanical contractor, the automatic controls contractor, the testing and balancing contractor, the testing contractor(s), the electrical contractor, the smoke control / life safety systems contractor, equipment manufacturers and suppliers, the commissioning authority, and others as required. The scope of work needs to identify the skills and qualifications of the commissioning team. The specification must include a section for each trade involved in the construction of the HVAC system, detailing its scope of work in the commissioning process. The specification must specifically define the party responsible for certifying that construction of the HVAC system is completed. A list of general commissioning specification requirements is in 12.3 of the guideline text.

Following this overview are sample commissioning statements relating to commissioning to be included in project specification and a limited outline of a commissioning specification for commissioning an HVAC system. Actual projects implementing the commissioning process may not require specifications that are as comprehensive as these examples.

These examples are predicated on the use of the Construction Specification Institute (CSI) format.

The sample statement relating to commissioning, to be included in Division 1, conveys to all parties that the commissioning process is being employed. Submittals are included in section 01300 to clearly indicate the format for submittals. Operations and maintenance instructions, training, and commissioning requirements are included in section 15010, Mechanical General Provisions, indicating the location of the detailed information for each of these items. This information is required for all equipment specified in Division 15 and should be included in Part 1- General, of each Division 15 section. The 15995 sample outline is provided to indicate the commissioning section specification requirements to achieve a successful commissioning process.

A6.2. Sample Commissioning Statements Relating to Commissioning to be Included in Specification

DIVISION 1—GENERAL REQUIREMENTS

Commissioning

- A. Commissioning services covering HVAC and electrical systems are specified in Section 01440 - Contractor Quality Control, Section 15995 - Commissioning of HVAC System, and Section 16995 - Commissioning of Electrical System. The contractor shall include all personnel, time, and resources as required to ensure that the commissioning is accomplished as specified.

SECTION 01300—SUBMITTALS

Submittals

- A. Manufacturers' standard dimension drawings and performance and product data shall be edited to delete reference to equipment, features, or information that is not applicable to the equipment being supplied for this project.
- B. Provide sufficient copies of approved data, with the engineers-approved stamp for inclusion in the operation and maintenance manuals as specified in Section 15995 - Commissioning of HVAC System.
- C. Part-load operation.

SECTION 15010—MECHANICAL GENERAL PROVISIONS

Operation and Maintenance Instructions

- A. Refer to Section 15995 - Commissioning of HVAC System for detailed operation and maintenance instruction requirements.

Training

- A. Refer to Section 15995 - Commissioning of HVAC System for detailed training requirements.

Commissioning

- A. Each subcontractor and supplier of equipment shall include in his/her quoted price the cost of furnishing the material requested and the manpower necessary for the operation and maintenance manuals, training, and system verification as specified under Section 15995 - Commissioning of HVAC System.

IN DIVISION 15—EQUIPMENT SECTIONS

The following paragraphs are to be included in Part 1 - General of each section of the specifications where equipment is specified and submittal data are to be provided. This is to include water treatment, pumps, boilers, chillers, air-handling units, air-conditioning units, fans, terminal boxes, ice builders, and controls.

Submittals

Submittals shall be made in accordance with the requirements of Section 01300 - Mechanical General Provisions. The vendor is cautioned that the requirements for deleting by marking out reference to any parts of the standard product literature that does not apply to this project will be strictly enforced.

Operations and Maintenance Instructions

Operations and maintenance instructions shall be submitted in accordance with the requirements of Section 15995 - Commissioning of HVAC System. The vendor is cautioned that the requirements for deleting by marking out reference to any parts of the standard product literature that does not apply to this project will be strictly enforced.

Training of Owners' Operators

The supplier of the equipment shall provide the services of a service engineer or factory-trained representative to conduct classroom training and hands-on sessions on the operation and maintenance of the equipment. This shall conform to the requirements of Section 15995 - Commissioning of HVAC System.

A6.3. Sample Specification Outline for Section 15995 - Commissioning of HVAC System

Note: Check all trade and component specifications for reference to this section.

PART 1—GENERAL REQUIREMENTS

- 1.1 Intent
- 1.2 Commissioning Team
 - A. Organizational Structure
 - B. General Qualifications
- 1.3 Scope of Work
- 1.4 Equipment and Instrumentation
- 1.5 Documentation
- 1.6 Training

PART 2 - PRODUCTS

None used

PART 3 - EXECUTION

- 3.1 Documentation
 - A. Scope
 - B. Construction-Phase Documentation
 - 1) Review of Equipment and Systems Submittals
 - 2) Construction-Phase Commissioning Plan
 - 3) Review Submitted TAB, Verification, and FPT Procedures (*refer to 12.5*)
 - C. Acceptance-Phase Documentation
 - 1) Operations and Maintenance Manuals
 - 2) Verification Records
 - 3) Functional Performance Test Records
 - 4) As-Built Documentation
 - 5) Systems Manual
 - 6) Commissioning Report
 - 7) Documentation Review
- 3.2 Meetings
- 3.3 Construction Observations and Inspections
 - A. Purpose
 - B. General Scope
 - C. Chiller
 - D. Heating and Cooling Equipment
 - E. Specialty Equipment and Systems
 - F. Duct Insulation
 - G. Ductwork and Diffusers
 - H. Air Distribution
 - I. Piping Systems
- 3.4 Pre Start-Up and Equipment Tests
 - A. Lubrication
 - B. Piping Cleaning
 - C. Piping Test
 - D. Duct Leakage Test
 - E. Air-Handling Units
- 3.5 Equipment Start-Up
 - A. Pumps
 - B. Variable-Frequency Drives
 - C. Package Chillers and Compressors
 - D. Cooling Tower
 - E. Boilers
- 3.6 Control System Calibration
- 3.7 Testing and Balancing
- 3.8 Verification (*see section A7 for details*)
 - A. Scope
 - B. Responsible Parties and Participants
 - C. Documentation Requirements
 - D. Instrumentation
 - E. Procedures
 - F. Air Distribution Systems
 - G. Piping Systems
 - H. HVAC Control Systems
 - I. Interface with Life Safety Systems
 - J. Air Quality
- 3.9 Certification of Completion of Construction
- 3.10 Functional Performance Testing (*see section A7.1 for detail*)
 - A. Scope
 - B. Submittals
 - C. Responsible Party and Participants

- D. Instrumentation
 - E. Procedures
 - F. Documentation and Reporting Requirements
 - G. Air-Handling Units
 - H. Chiller or Chilled-Water Supply System
 - I. Cooling Tower or Heat Rejection System
 - J. Boiler or Hot Water Systems
 - K. Room Tests
 - L. Opposite Season Test
- 3.11 Training
 - A. O&M Training Programs
 - B. Systems Training
 - C. Documentation
 - 3.12 Post-Acceptance Activities

A6.4. Example of an Actual Commissioning Specification Used in the Field on a Large Commercial Design-Bid Construction Project

DIVISION 1

SECTION 01650 - GENERAL REQUIREMENTS

PART 1 - GENERAL

1.01 Description

A. The purpose of the commissioning process is to provide the Owner / operator of the facility with a high level of assurance that the mechanical and electrical systems have been installed in the prescribed manner, and operate within the performance guidelines set in the design intent. The Commissioning Authority shall provide the Owner with an unbiased, objective view of the system's installation, operation, and performance. This process is not to take away or reduce the responsibility of the design professionals or installing contractors to provide a finished product. Commissioning is intended to enhance the quality of system start-up and aid in the orderly transfer of systems to beneficial use by the owner. The Commissioning Authority will be a member of the construction team, cooperating and coordinating all commissioning activities with the design professionals, construction manager, contractors, subcontractors, manufacturers and equipment suppliers.

1.02 Scope

A. The functions and responsibility of the Commissioning Authority shall include:

1. Responsibility: The primary point of responsibility is to inform the General Contractor (Construction Manager) and the Owner on the status, integration, and performance of systems within the facility.

2. Information: The Commissioning Authority shall function as a catalyst and initiator to disseminate information and assist the design and construction teams in the completion of the construction process. This shall include system completeness, performance, and adequacy to meet the intended performance standards of each system. Services include construction observation, spot testing, verification and functional performance testing, and providing performance and operat-

ing information to the responsible parties, e.g., contractors, design professionals, and the Owner.

3. Quality Assurance: Assist the responsible parties to maintain a high quality level of installation and system performance.

4. Observation of tests: Commissioning Authority shall observe and coordinate testing as required to ensure system performance meets the design intent.

5. Documentation of tests: Commissioning Authority shall document the results of the performance testing directly and/or ensure that all testing is documented by the appropriate technicians. The Commissioning Authority shall provide standard forms to be used by all parties for consistency of approach and type of information to be recorded.

6. Resolution of disputes: The Commissioning Authority is to remain an independent party present on the project with specific knowledge of the project. Should disputes arise, the Commissioning Authority shall perform research to determine the scope and extent of the problem and educate the involved parties as to the nature and extent of the problem. This shall include technical and financial aspects of the dispute, including assistance to help identify who the responsible parties are to implement corrective action. The Owner / Architect shall preside over resolution of the problem.

7. Deficiencies: Provision of technical expertise to oversee and verify the correction of deficiencies found during the commissioning process.

8. Acceptance: The Commissioning Authority shall determine and advise the Construction Manager and Owner of the date of acceptance for each component and system for start of the warranty period.

9. Provision of technical expertise to review and edit operating and maintenance descriptions by system.

B. The Commissioning Agency is referred to as an independent contractor in this Division and shall work under a separate contract directly for the Owner.

C. The Commissioning Agency shall not be financially associated with any of the Division 2 through 16 contractors on this project to avoid potential conflicts of interest.

1.03 Systems to be Included in Commissioning Process

The following pieces of equipment and systems shall go through commissioning:

1. Electric heating systems
2. Hydronic distribution systems
3. Air handling / air distribution systems
4. Domestic hot water systems
5. Variable frequency drives
6. Fire protection / suppression systems
7. Fire detection and alarm systems
8. Electrical main switchgear and power systems
9. Lighting systems (dimming)
10. Motor control centers
11. Stand-by power systems
12. DDC / EMCS control systems, hardware, software, and documentation
13. UPS systems
14. Glazing
15. Insulation

16. Other

- a. Indoor air quality (IAQ)
- b. Computer room AC (as applicable)
- c. Kitchen HVAC
 1. exhaust systems
 2. cooking equipment
 3. walk-in coolers

1.04 Coordination

A. The Commissioning Authority shall receive a copy of all construction documents, addenda, change orders, and appropriate approved submittals and shop drawings directly from the design professional(s) and Construction Manager.

B. The Commissioning Authority shall disseminate written information and documents to all responsible parties relative to the nature and extent of the communication.

C. The Commissioning Authority is primarily responsible to the Owner, and as such, shall regularly apprise the Construction Manager and the Owner of progress, pending problems and/or disputes, and shall provide regular status reports on progress with each system. Any potential change in the contractual and/or financial obligations of the owner (credits, change orders, schedule changes, etc.) shall be identified and quantified as soon as possible.

D. The Commissioning Authority shall coordinate the schedule of commissioning activities with the construction schedule. It is possible that some procedures will be completed before the entire HVAC system is completed.

1.05 Schedule

A. Commissioning of systems shall proceed per the criteria established in the specific sections that follow, with activities to be performed on a timely basis. The Commissioning Authority shall be available to respond promptly to avoid construction delays.

B. Start-up and testing of systems may proceed prior to final completion of systems to expedite progress. However, the Commissioning Authority shall not perform testing and checkout services that are the primary responsibility of the contractor / vendor in advance of their testing and checkout.

C. Problems observed shall be addressed immediately, responsible parties notified, and actions to correct deficiencies coordinated in a timely manner.

D. Contractor schedules and scheduling is the responsibility of the Construction Manager. The Commissioning Authority shall provide commissioning scheduling information to the Construction Manager for review and planning activities.

1.06 Related Work Specified Elsewhere

A. Commissioning requires support from the contractors. The commissioning process does not relieve any contractors from their obligations to complete all portions of work in a satisfactory manner.

B. Refer to Sections 15995 and 16970 for Division 15 and 16 contractor responsibilities relative to the commissioning process.

Note that Section 16970 and Division 16 responsibilities are not included in this example.

PART 2 - PRODUCTS

2.01 Test Equipment

A. All industry standard test equipment required for performing the specified tests shall be provided by the Commissioning Authority. Any proprietary vendor specific test equipment shall be provided by that vendor or manufacturer.

B. Any portable or hand-held setup / calibration devices required to initialize the control system shall be made available by the control vendor (at no cost) to the Commissioning Authority.

C. The Commissioning Authority's instrumentation shall meet the following standards:

1. Be of sufficient quality and accuracy to test and/or measure system performance within the tolerances required.
2. Be calibrated at the manufacturer's recommended intervals with calibration tags permanently affixed to the instrument
3. Be maintained in good repair and operating condition throughout the duration of use on this project.
4. Be immediately re-calibrated or repaired if dropped and/or damaged in any way during use on this project.

PART 3 - EXECUTION

3.01 Commissioning Plan and Schedule

A. The Commissioning Authority shall develop and submit a schedule for the commissioning process which is integrated with the construction schedule. Included shall be the required work by all team members (Commissioning Authority, design team, contractors, and the Owner). Overlay with the construction schedule, and include time for test and balance, verification, and functional performance testing.

3.02 Construction Observation

A. This is an additional and separate activity from that provided by the design team. Construction observation is required as part of the commissioning and coordination process to be provided by the Commissioning Authority.

3.03 Test and Balance

A. Air and water balance shall be accomplished by an independent test and balance firm. The Commissioning Authority shall spot check this work to verify accuracy of results.

3.04 Verification and Functional Performance Test Procedures

A. Personnel experienced in the technical aspects of each system to be commissioned shall develop and document the commissioning procedure to be used. Include a performance checklist and performance test data sheets for each system based on actual system configuration. These procedures shall be reviewed by the appropriate design engineers for technical depth, clarity of documentation and completeness. Special emphasis shall be placed on testing procedures that shall conclusively determine actual system performance and compliance with the design intent.

B. The majority of mechanical equipment requires safety devices to stop and/or prevent equipment operation unless minimum safety standards or conditions are met. These may include adequate oil pressure, proof-of-flow, non freezing conditions, maximum static pressure, maximum head pressure, etc. The Commissioning Authority shall observe the actual performance of safety shutoffs in a real or closely simulated condition of failure.

C. Systems may include safety devices and components that control a variety of equipment operating as a system. Interlocks may be hard-wired or operate from software. Operation of these interlocks shall be verified by the Commissioning Authority.

D. The Commissioning Authority shall determine the acceptance procedures for each system within Divisions 15 and 16 disciplines. The acceptance procedures shall incorporate the commissioning standards and successful testing results as referred to throughout Division 15 and 16 specifications.

1. In particular, the temperature control system shall have all I/O points individually verified for proper function, calibration, and operation. The Commissioning Authority shall review proposed testing procedures and report formats, and observe sufficient field testing to confirm that all I/O points have been properly tested.
2. All control sequence of operation strategies, alarm generation and reporting shall also be reviewed and proper operation verified by the Commissioning Authority.
3. The central work station graphics, point assignments, alarm messages, and logging functions shall be verified.

E. The appropriate contractor and vendor(s) shall be informed of what tests are to be performed and the expected results. Whereas some test results and interpretations may not become evident until the actual tests are performed, all parties shall have a reasonable understanding of the requirements. The Commissioning Plan shall address those requirements and be distributed to all parties involved with that particular system.

F. Acceptance procedures shall confirm the performance of systems to the extent of the design intent. When a system is accepted, the Owner shall be assured that the system is complete, works as intended, is correctly documented, and operator training has been performed.

3.05 Functional Performance Testing - Observation

A. The functional performance testing shall be done by the testing contractor. The Commissioning Authority shall direct and witness all of these tests.

B. Tests shall be completed comprehensively and to the extent necessary to enable the Commissioning Authority to assure the Owner and design professional that the systems do perform per the design intent.

3.06 Software Documentation Review

A. Review detailed software documentation for all DDC control systems. This includes review of vendor documentation, their programming approach, and the specific software

routines applied to this project. Discrepancies in programming approaches and/or sequences shall be reported and coordinated in order to provide the Owner with the most appropriate, simple, and straightforward approach to software routines.

3.07 Operating and Maintenance (O&M) Manuals

A. The Commissioning Authority shall review the draft form of the O&M manuals provided by the Division 15 contractor and the Division 16 contractor. The review process shall verify that O&M instructions meet specifications and are included for all equipment furnished by the contractor, and that the instructions and wiring diagrams are specific (edited where necessary) to the actual equipment provide for this project.

Published literature shall be specifically oriented to the provided equipment indicating required operation and maintenance procedures, parts lists, assembly / disassembly diagrams, and related information.

The contractor shall incorporate the standard technical literature into system specific formats for this facility as designed and as actually installed. The resulting O&M information shall be system specific, concise, to the point, and tailored specifically to this facility. The Commissioning Authority shall review and edit these documents as necessary for final corrections by the contractor.

B. The O&M manual review, and coordination efforts shall be completed prior to Owner training sessions, as these documents are to be utilized in the training sessions.

3.08 Training

Schedule and coordinate training sessions for the Owner's staff for each system. Training shall be in a classroom setting with the appropriate schematics, handouts, and visual / audio training aids on-site with equipment.

A. The Commissioning Authority organizes, schedules, and directs the training sessions.

B. The appropriate installing contractors shall provide training on all the major systems per specifications, including peculiarities specific to this project.

C. The equipment vendors shall provide training on the specifics of each major equipment item including philosophy, troubleshooting, and repair techniques.

D. The automatic control and fire alarm vendors shall provide training on the control system and fire alarm system per their specification section.

3.09 Record Drawings

A. The Commissioning Authority shall review the as-built contract documents to verify incorporation of both design changes and as-built construction details. Discrepancies noted shall be corrected by the appropriate party.

3.10 Exclusions

A. Responsibility for construction means and methods: The Commissioning Authority is not responsible for construction means, methods, job safety, or any construction management functions on the job site.

B. Hands-on work by the Commissioning Authority: The contractors shall provide all services requiring tools or the use of tools to start-up, test, adjust, or otherwise bring equipment and systems into a fully operational state. The Commissioning Authority shall coordinate and observe these procedures (and may make minor adjustments), but shall not perform construction or technician services other than verification of testing, adjusting, balancing, and control functions.

DIVISION 15

SECTION 15995 - MECHANICAL

PART 1 - GENERAL

1.01 Definition

A. The purpose of this section is to specify the Division 15 responsibilities and participation in the commissioning process.

B. Work under this contract shall conform to requirements of Division 1, General Requirements, Conditions of the Contract, and Supplementary Conditions. This specification covers commissioning of mechanical systems which are part of this project.

C. Commissioning work shall be a team effort to ensure that all mechanical equipment and systems have been completely and properly installed, function together correctly to meet the design intent, and document system performance parameters for fine tuning of control sequences and operational procedures. Commissioning shall coordinate system documentation, equipment start-up, control system calibration, testing and balancing, and verification and performance testing.

D. The commissioning team shall be made up of representatives from the owner, design professionals, major equipment suppliers, and construction trades. The trades represented on the commissioning team shall include, but not be limited to, sheet metal, piping and fitting, controls, test and balance, and electrical. The lead person for each trade who will actually perform or supervise the work is to be designated as the representative to the commissioning team. Responsibility for various steps of the commissioning process shall be divided among the members of the commissioning team, as described in this section.

E. The Commissioning Authority shall have responsibility for coordinating and directing each step of the commissioning process.

F. Mechanical system installation, start-up, testing, balancing, preparation of O&M manuals, and operator training are the responsibility of the Division 15 Contractors, with coordination, observation, verification and commissioning the responsibility of Division 1, Section 01650. The 01650 commissioning process does not relieve Division 15 from the obligations to complete all portions of work in a satisfactory and fully operational manner.

1.02 Scope of Work

A. Commissioning work of Division 15 shall include, but not be limited to:

1. Testing and start-up of the equipment.

2. Testing, adjusting and balancing of hydronic and air systems.
3. Cooperation with the Commissioning Authority.
4. Providing qualified personnel for participation in commissioning tests, including seasonal testing required after the initial testing.
5. Providing equipment, materials, and labor as necessary to correct construction and/or equipment deficiencies found during the commissioning process.
6. Providing operation and maintenance manuals, and as-built drawings to the Commissioning Authority for verification.
7. Providing training and demonstrations for the systems specified in this Division.

B. The work included in the commissioning process involves a complete and thorough evaluation of the operation and performance of all components, systems, and sub-systems. The following equipment and systems shall be evaluated:

1. Automatic temperature controls
2. Air handling systems
3. Hydronic distribution systems
4. Electric heating systems
5. Air distribution and exhaust systems
6. Domestic hot water systems
7. Variable frequency drives
8. Fire protection / suppression systems
9. DDC / EMCS control systems
10. Other
 - a. Indoor air quality (IAQ)
 - b. Computer room AC (as applicable)
 - c. Kitchen HVAC

C. Timely and accurate documentation is essential for the commissioning process to be effective. Documentation required as part of the commissioning process shall include but not be limited to:

1. Progress and status reports, including deficiencies noted.
2. Minutes from all meetings.
3. Pre-start, and start-up procedures.
4. Training agenda and materials.
5. As-built records.
6. Commissioning report.
7. Operation and maintenance (O&M) manuals.

D. Detailed testing shall be performed on all installed equipment and systems to ensure that operation and performance conform to contract documents. All tests shall be witnessed by the Commissioning Authority. The following testing is required as part of the commissioning process:

1. Verification tests are comprised of a full range of checks and tests to determine that all components, equipment, systems, and interfaces between systems operate in accordance with contract documents. This includes all operating modes, interlocks, control responses, and specific responses to abnormal or emergency conditions.
2. Functional performance tests (FPT) shall determine if the HVAC system is providing the required cooling and heating services in accordance with the finalized

design intent. These tests shall also determine the installed capacity of the cooling and heating plant, and the individual heat transfer components.

E. Comprehensive training of O&M personnel shall be performed by the Mechanical Contractor, and where appropriate, by other sub-contractors, and vendors prior to turnover of building to the owner. The training shall include classroom instruction, along with hands-on instruction on the installed equipment and systems.

1.03 Roles and Responsibilities

All parties involved in the construction process shall be involved in the commissioning process. Following is a description of the responsibilities of each party:

A. Owner

1. Assign maintenance personnel and schedule them to participate in meetings, training sessions and inspections as follows:
 - a. Construction Phase coordination meeting.
 - b. Initial Owner training session at initial placement of major equipment.
 - c. Maintenance orientation and inspection.
 - d. Piping and ductwork test and flushing verification meetings.
 - e. Procedures meeting for Testing, Adjusting and Balancing.
 - f. Owners training session.
 - g. Verification demonstrations.
 - h. Final review at acceptance meeting.
2. Provide qualified personnel for video taping and editing of training sessions.
3. Video tape construction progress, hidden shafts, etc. (optional).
4. Provide any utilities required for the commissioning process.
5. Provide detailed program clearly stating the Owner's objectives, parameters, budgets, etc. for this facility.

B. Commissioning Authority

1. Develop the commissioning requirements and all related testing, verification and quality control sections.
2. Prepare the mechanical commissioning program required as part of the Commissioning Specification. Include list of all contractors for commissioning events by name, firm and trade specialty.
3. Execute the mechanical commissioning program, through organization of all meetings, tests, demonstrations, training events and performance verifications described in the Contract Documents and approved HVAC commissioning program. Organizational responsibilities include preparation of agendas, attendance lists, arrangements for facilities and timely notification to participants for each commissioning event. The Commissioning Authority shall act as chairman at all commissioning events and assure execution of all agenda items. The Commissioning Authority shall prepare minutes of every commissioning event and send copies to all attendees and the Owner within 5 work days of the event.

4. Review the design documents for their affect on the commissioning process and the final performance of the HVAC system. This includes ensuring that appropriate commissioning guidelines have been followed, and that there are adequate devices included in the design to ensure the ability to properly test, adjust, and balance the systems, and to document the performance of each piece of equipment and each system. Any items required but not shown shall be brought to the attention of the Contractor prior to submittal of shop drawings.
5. Review all submittals (e.g. equipment, ductwork, piping, automatic controls, and TAB procedures) for their affect on the commissioning process and the final performance of the HVAC system.
6. Schedule the Construction Phase coordination meeting within 90 days of the award of the contract, at some convenient location and at a time suitable to the Contractor and Design Professional. This meeting shall be for the purpose of reviewing the complete mechanical commissioning program and establishing tentative schedules for mechanical system orientation and inspections, O&M submittals, training sessions, system flushing and testing, job completion, test, adjust and balance (TAB) work, and verification and functional performance testing.
7. Schedule the initial Owner training session so that it will be held immediately before the mechanical system orientation and inspection. This session shall be attended by the Owner's O&M personnel, the mechanical Contractor, the Design Professional and the Commissioning Authority. The Design Professional shall conduct this session giving an overview of the system, the system design goals and the reasoning behind the selection of the equipment.
8. Conduct periodic inspections of work in progress to ensure that all systems and equipment are installed according to specifications.
9. Conduct the Mechanical system orientation and inspection following the initial training session. The Mechanical system orientation and inspection shall be conducted by the mechanical Contractor. The emphasis of this Mechanical system orientation and inspection shall be an observation of the equipment location with respect to accessibility. Prepare minutes of this meeting, with separate summary of deficiency findings by the Owner and Commissioning Authority. Distribute to attendees and the Owner
10. Receive and review the Operation and Maintenance (O&M) manuals as submitted by the contractor, ensuring that they follow the specified outline and format. Insert systems description as provided by the Design Professional.
11. Adequate accessibility for maintenance and component replacement or repair is the Construction Manager's responsibility and shall be checked by the Commissioning Authority.
12. Witness equipment and system start-up and testing. Ensure the results are documented (including a summary of deficiencies), and incorporated in the O&M manuals.
13. Prior to initiating the TAB work, the Commissioning Authority shall meet with the Owner, mechanical Contractor, Design Professional and TAB Contractor. The TAB Contractor shall outline TAB procedures and get concurrence from the Design Professional and Commissioning Authority. Ensure that the TAB Contractor has all forms required for the job database and understands their importance and use.
14. Schedule the O&M training sessions. These training sessions are to be attended by the Owner, Commissioning Authority, Design Professional, Construction Manager, Contractors and equipment suppliers as necessary. The format shall follow the outline in the O&M manuals. This mechanical system orientation and inspection should include hands on training.
15. Submit detailed verification test procedures and data sheets for review by the Design Professional.
16. Submit detailed FPT procedures for review and acceptance by the Design Professional.
17. Upon receipt of notification from the Design Professional that the mechanical systems have been completed and are operational, the Commissioning Authority shall proceed to verify the TAB report and operation of the control systems in accordance with the Commissioning Specification.
18. Conduct verification tests.
19. Submit verification test data for review to the Design Professional for review and acceptance.
20. Provide detailed checklist data sheets to document verification tests.
21. Provide and install calibrated test instrumentation to monitor and record data as necessary.
22. The Commissioning Authority shall certify that the mechanical systems are ready for Functional Performance Testing.
23. Conduct Functional performance tests. The test data shall be part of the commissioning report.
24. Submit functional performance test report for review to the Design Professional.
25. Re-test if performance deficiencies are found, corrected, and additional testing is requested.
26. Review as-built drawings for accuracy with respect to the installed systems. Request revisions to achieve accuracy.
27. Ensure that the O&M manuals, and all other as-built records have been updated to include all modifications made during the construction phase.
28. Repeat Functional Performance Tests to accommodate seasonal tests and/or correct any performance deficiencies. Revise and re-submit the commissioning report.
29. Prepare the final commissioning report.
30. Assemble the final project documentation which shall include the commissioning report, and all as-built records. Submit this documentation to the Design Professional for review and acceptance.

C. Architect

1. Provide support to the Design Professional who must provide a service as a part of the commissioning process. This shall include providing adequate space for equipment installation and maintenance.
2. Include Section 01650 regarding commissioning in Division 1 - General Requirements alerting all parties to the need to participate.
3. Conduct periodic inspections of work in progress to ensure that all systems and equipment are installed according to specifications.
4. Provide data (MSDS) on structure, building materials, interior finishes, and furnishings for their effect on indoor air quality.

D. Mechanical Design Professional

1. Provide documentation of initial design concepts, and Design Intent based on the Owner's program.
2. Provide mechanical system design parameters and obtain approval of Owner.
3. Prepare contract documents incorporating the Commissioning Specification requirements, and description of the mechanical system.
4. The Design Professional shall specify and verify adequate maintenance accessibility for each piece of equipment in shop drawings and the actual installation. Periodic inspections are part of the Design Professional's construction administration duties.
5. The Design Professional retains responsibility for the system evaluation, adequacy of the system to meet design intent, capacity of the system, quality control check or any of the other elements of the system design.
6. Attend the Owner training sessions. Conduct the mechanical training session pertaining to the overview of the system design, the system design goals and the reasoning behind the selection of equipment.
7. Participate in O&M personnel orientation and inspection at the final construction stage.
8. Attend initial meeting with TAB representative as scheduled by Commissioning Authority.
9. Review verification and functional performance testing procedures submitted by the Commissioning Authority.
10. Review TAB report and verification data sheets for system conformance to contract documents. Issue a report noting deficiencies requiring correction to the Commissioning Authority.
11. Review functional performance testing report for deficiencies in meeting the finalized design intent.
12. Review as-built records as required by contract documents and turn them over to the Commissioning Authority for inclusion in final project documentation.
13. Review and comment on the final commissioning report.

E. Construction Manager

1. Include cost for commissioning requirements in the contract price.

2. Include commissioning requirements in the mechanical, electrical, and controls contracts, as well as all other sub-contractors, to ensure full cooperation of all parties in the mechanical commissioning program.
3. Ensure acceptable representation, with the means and authority to prepare and coordinate execution of the mechanical commissioning program as described in the contract documents.
4. Issue a statement that TAB work has been completed, and submit the final TAB reports for review.
5. Issue a statement that control systems have been calibrated.
6. Remedy deficiencies identified in verification tests.
7. Evaluate any performance deficiencies identified in the FPT report for non-conformance with contract documents.

F. Mechanical Contractor

1. Include cost to complete commissioning requirements for mechanical systems in the contract price.
2. Include requirements for submittal data, O & M data, and training in each purchase order or sub-contract written.
3. Ensure cooperation and participation of specialty sub-contractors such as sheet metal, piping, refrigeration, water treatment, and TAB.
4. Ensure participation of major equipment manufacturers in appropriate training and testing activities.
5. Attend Construction Phase coordination meeting scheduled by the Commissioning Authority.
6. Assist the Commissioning Authority in all verification and functional performance tests.
7. Prepare preliminary schedule for mechanical system orientation and inspections, O&M manual submission, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, TAB, and task completion for use by the Commissioning Authority. Update schedule as appropriate throughout the construction period.
8. Attend initial training session.
9. Conduct mechanical system orientation and inspection at the equipment placement completion stage.
10. Update drawings to the record condition to date, and review with the Commissioning Authority.
11. Gather O&M data on all equipment, and assemble in binders as required by the Commissioning Specification. Submit to Commissioning Authority prior to the completion of construction.
12. Notify the Commissioning Authority a minimum of two weeks in advance, so that witnessing equipment and system start-up and testing can begin.
13. Notify the Commissioning Authority a minimum of two weeks in advance, of the time for start of the TAB work. Attend the initial TAB meeting for review of the TAB procedures.
14. Participate in, and schedule vendors and Contractors to participate in the training sessions as set up by the Commissioning Authority.

15. Provide written notification to the Construction Manager and Commissioning Authority that the following work has been completed in accordance with the contract documents, and that the equipment, systems, and sub-systems are operating as required.
 - a. HVAC equipment including all fans, air handling units, dehumidification units, ductwork, dampers, terminals, and all Division 15 equipment.
 - b. Refrigeration equipment, pumping systems and heat rejection equipment.
 - c. Fire stopping in the fire rated construction, including fire and smoke damper installation, caulking, gasketing and sealing of smoke barriers.
 - d. Dedicated smoke control systems including stairway pressurization and atrium systems.
 - e. Non-dedicated systems using the air handling units for smoke control.
 - f. Fire detection and smoke detection devices furnished under other divisions of this specification as they affect the operation of the smoke control systems.
 - g. That building control systems are functioning to control mechanical equipment and smoke control systems.
16. Provide a complete set of as-built records to the Commissioning Authority.

G. Test, Adjust, and Balance Contractor

1. Include cost for commissioning requirements in the contract price.
2. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
3. Submit the TAB procedures to the Commissioning Authority and Design Professional for review and acceptance.
4. Attend the TAB review meeting scheduled by the Commissioning Authority. Be prepared to discuss the procedures that shall be followed in testing, adjusting and balancing the HVAC system.
5. Participate in training sessions as scheduled by the Commissioning Authority.
6. At the completion of the TAB work, and submittal of final TAB report, notify the mechanical Contractor and Construction Manager.
7. Participate in verification of the TAB report, which will consist of repeating any selected measurement contained in the TAB report where required by the Commissioning Authority for verification or diagnostic purposes.

H. Automatic Controls and Building Automation System Contractors

1. Include cost for commissioning requirements in the contract price.
2. Review design for controllability with respect to selected manufacturers equipment;
 - a. Verify proper hardware specification exists for functional performance required by specification and sequence of operation.
 - b. Verify proper safeties and interlocks are included in design.

- c. Verify proper sizing of control valves and actuators based on design pressure drops. Verify control valve authority to control coil properly.
 - d. Verify proper sizing of control dampers. Verify damper authority to control air stream. Verify proper damper positioning for mixing to prevent stratification. Verify actuator vs. damper sections for smooth operation.
 - e. Verify proper selection of sensor ranges.
 - f. Clarify all questions of operation.
3. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
4. Provide the following submittals to the Commissioning Authority;
 - a. Hardware and software submittals.
 - b. Control panel construction shop drawings.
 - c. Narrative description of each control sequence for each piece of equipment controlled.
 - d. Diagrams showing all control points, sensor locations, point names, actuators, controllers and, where necessary, points of access, superimposed on diagrams of the physical equipment.
 - e. Logic diagrams showing the logic flow of the system.
 - f. A list of all control points, including analog inputs, analog outputs, digital inputs, and digital outputs. Include the values of all parameters for each system point. Provide a separate list for each stand-alone control unit.
 - g. A complete control language program listing including all software routines employed in operating the control system. Also provide a program write-up, organized in the same manner as the control software. This narrative shall describe the logic flow of the software and the functions of each routine and sub-routine. It should also explain individual math or logic operations that are not clear from reading the software listing.
 - h. Hardware operation and maintenance manuals.
 - i. Application software and project applications code manuals.
5. Verify proper installation and performance of controls / BAS hardware and software provided by others.
6. Integrate installation and programming schedule with construction and commissioning schedules.
7. Provide thorough training to operating personnel on hardware operations and programming, and the application program for the system.
8. Demonstrate system performance to Commissioning Authority including all modes of system operation (e.g. normal, abnormal, emergency).
9. Provide control system technician for use during system verification and functional performance testing.
10. Provide system modifications as required.
11. Provide support and coordination with TAB contractor on all interfaces between their scopes of work. Provide all devices, such as portable operators terminals, for TAB use in completing TAB procedures.

12. Additional trend logs may be required to facilitate the commissioning process.

I. Equipment Suppliers and Miscellaneous Contractors

1. Include cost for commissioning requirements in the contract price.
2. Provide submittals, and appropriate O&M manual section(s).
3. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
4. Participate in training sessions as scheduled by the Commissioning Authority.
5. Demonstrate performance of equipment as applicable.

1.04 Documentation

A. The Commissioning Authority shall oversee and maintain the development of commissioning documentation. The commissioning documentation shall be kept in three ring binders, and organized by system and sub-system when practical. All pages shall be numbered, and a table of contents page(s) shall be provided. The commissioning documentation shall include, but not be limited to, the following:

1. A detailed description of the design intent for the project, listing operating parameters, control sequences, occupancy conditions, etc.
2. A complete description of how the HVAC system is intended to operate.
3. Approved test and balance report for the building being commissioned.
4. All accepted shop drawings of mechanical equipment. Shop drawings shall be full size sheets folded as required to fit in binders.
5. All pre-functional performance test checklists, signed by indicated personnel, organized by system and sub-system.
6. All verification and functional performance test checklists/results, signed by indicated personnel, organized by system and sub-system.
7. Three copies of the operation and maintenance (O&M) manuals specified in other sections of these specifications shall be included with the commissioning documentation. The manuals shall be incorporated in the commissioning documentation prior to commencement of O&M training required in this and other sections of the specification. Preparation of O&M manuals shall be as specified in section 3.07 of these specifications.

PART 2 - PRODUCTS

2.01 Test Equipment

A. The appropriate Contractor(s) shall furnish all special tools and equipment required during the commissioning process. A list of all tools and equipment to be used during commissioning shall be submitted to the Commissioning Authority for approval. The owner shall furnish necessary utilities for the commissioning process.

2.02 Test Equipment - Proprietary

A. Proprietary test equipment and software required by any equipment manufacturer for programming and/or start-up, whether specified or not, shall be provided by the manufacturer of the equipment. Manufacturer shall provide the test equipment, demonstrate its use, and assist in the commissioning process as needed. Proprietary test equipment (and software) shall become the property of the owner upon completion of the commissioning process.

PART 3 - EXECUTION

3.01 General

A. A pre-construction meeting of all commissioning team members shall be held at a time and place designated by the owner. The purpose shall be to familiarize all parties with the commissioning process, and to ensure that the responsibilities of each party are clearly understood.

B. The Contractor shall complete all phases of work so the systems can be started, tested, balanced, and acceptance procedures undertaken. This includes the complete installation of all equipment, materials, pipe, duct, wire, insulation, controls, etc., per the contract documents and related directives, clarifications, and change orders.

C. A Commissioning Plan shall be developed by the Commissioning Authority. The Contractor shall assist the Commissioning Authority in preparing the Commissioning Plan by providing all necessary information pertaining to the actual equipment and installation. If contractor initiated system changes have been made that alter the commissioning process, the Commissioning Authority shall notify the Owner.

D. Acceptance procedures are normally intended to begin prior to completion of a system and/or sub-systems, and shall be coordinated with the Division 15 contractor. Start of acceptance procedures before system completion does not relieve the contractor from completing those systems as per the schedule.

3.02 Participation In Acceptance Procedures

A. The Contractor shall provide skilled technicians to start-up and debug all systems within Division 15. These same technicians shall be made available to assist the Commissioning Authority in completing the commissioning program. Work schedules, time required for testing, etc., shall be requested by the Commissioning Authority and coordinated by the contractor. Contractor shall ensure that the qualified technician(s) are available and present during the agreed upon schedules and of sufficient duration to complete the necessary tests, adjustments, and/or problem resolutions.

B. System performance problems and discrepancies may require additional technician time, Commissioning Authority time, reconstruction of systems, and/or replacement of system components. The additional technician time shall be made available for subsequent commissioning periods until the required system performance is obtained.

C. The Commissioning Authority reserves the right to question the appropriateness and qualifications of the technicians relative to each item of equipment, system, and/or sub-system. Qualifications of technicians shall include expert knowledge relative to the specific equipment involved and a

willingness to work with the Commissioning Authority. Contractor shall provide adequate documentation and tools to start-up and test the equipment, system, and/or sub-system.

3.03 Deficiency Resolution

A. In some systems, misadjustments, misapplied equipment, and/or deficient performance under varying loads will result in additional work being required to commission the systems. This work shall be completed under the direction of the Owner, with input from the contractor, equipment supplier, and Commissioning Authority. Whereas all members shall have input and the opportunity to discuss, debate, and work out problems, the Owner and/or Architect shall have final jurisdiction over any additional work done to achieve performance.

B. Corrective work shall be completed in a timely fashion to permit the completion of the commissioning process. Experimentation to demonstrate system performance may be permitted. If the Commissioning Authority deems the experimentation work to be ineffective or untimely as it relates to the commissioning process, the Commissioning Authority shall notify the Owner, indicating the nature of the problem, expected steps to be taken, and suggested deadline(s) for completion of activities. If the deadline(s) pass without resolution of the problem, the Owner reserves the right to obtain supplementary services and/or equipment to resolve the problem. Costs incurred to solve the problems in an expeditious manner shall be the contractor's responsibility.

3.04 Additional Commissioning

A. Additional commissioning activities may be required after system adjustments, replacements, etc., are completed. The contractor(s) suppliers, and Commissioning Authority shall include a reasonable reserve to complete this work as part of their contractual obligations.

3.05 Seasonal Commissioning

A. Seasonal commissioning pertains to testing under full load conditions during peak heating and peak cooling seasons, as well as part load conditions in the spring and fall. Initial commissioning shall be done as soon as contract work is completed, regardless of season. Subsequent commissioning may be undertaken at any time thereafter to ascertain adequate performance during the different seasons.

B. Heating equipment shall be tested during winter design extremes. Cooling equipment shall be tested during summer design extremes with a fully occupied building. Each contractor and supplier shall be responsible to participate in the initial and the alternate peak season tests of the systems as required to demonstrate performance.

3.06 Acceptance Procedures

A. Verification Tests

1. Scope of verification tests

- a. Operating tests and checks to verify that all components, equipment, systems, sub-systems, and interfaces between systems, operate in accordance with contract documents. These tests are to include all operating modes, interlocks, specified control responses, specific responses to abnormal or emergency condi-

tions, and verification of the proper response of the building automation system controllers and sensors.

- b. Verify the validity of the TAB report.

2. Participants in verification tests

The Commissioning Authority shall be responsible for preparing the scope of these tests. The Commissioning Authority shall schedule the tests and assemble the commissioning team members who shall be responsible for the tests. Participating contractors, manufacturers, suppliers, etc. shall include all costs to do the work involved in these tests in their proposals. Following is a list of tasks and supporting information that shall be required:

- a. Mechanical contractor - provide the services of a technician(s) who is (are) familiar with the construction and operation of this system. Provide access to the contract plans, shop drawings, and equipment cut sheets of all installed equipment.
- b. Controls contractor - provide the services of a controls engineer who is familiar with the details of the project. Provide details of the control system, schematics, and a narrative description of control sequences of operation.
- c. Electrical contractor - provide a foreman electrician familiar with the electrical interlocks, interfaces with emergency power supply, and interfaces with alarm and life-safety systems. Provide access to the contract plans, and all as-built schematics of sub-systems, interfaces, and interlocks.

3. Documentation and Reporting Requirements

- a. Provide checklists for each component, piece of equipment, system, and sub-system, including all interfaces, interlocks, etc. Each item to be tested shall have a different entry line with space provided for comments. Separate checklists shall be prepared for each mode of operation. Provide space to indicate whether the mode under test responded as required or not. Also, provide space for all necessary parties to sign off on each checklist.
- b. Data sheets used in verification of the proper operation of the control system shall include each controller to be verified, the system it serves, the service it provides, and its location. For each controller, provide space for recording the readout of the controller, the reading at the controller's sensor(s), and any comments. Also, provide space for all necessary parties to sign off on each checklist.
- c. All test procedures and data sheets shall be submitted to the design professional for review and acceptance.

4. Instrumentation

- a. The Commissioning Authority shall furnish all measurement instrumentation for the verifica-

tion tests. All instruments will have been calibrated within the six month period prior to these tests.

5. Verification Procedures

- a. The Commissioning Authority shall direct and witness the verification operating tests and checks for all equipment and systems.
 1. Set the system equipment (i.e. chiller, boiler, pumps, fans, etc.) into the operating mode to be tested, i.e. normal shut down, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions.
 2. The Commissioning Authority shall inspect and verify the position of each device and interlock identified on the checklist. Each item shall be signed off as acceptable (yes), or failed (no).
 3. This test shall be repeated for each operating cycle that applies to the mechanical system being tested.
 4. Operating checks shall include all safety cutouts, alarms, and interlocks with smoke control and life safety systems during all modes of operation of the mechanical system.
 5. If during a test an operating deficiency is observed, appropriate comments shall be added to the checklist data sheet.
 6. Verification of the interface of the monitoring and control system, and the TAB criteria shall include the following:
 - a. Verify supply and return flow rates for VAV and constant volume systems in all modes of operation of the HVAC system.
 - b. Verify operation of the terminal units in both heating and cooling cycles.
 - c. Verify minimum outdoor air intake in all modes of operation and at minimum and maximum total air flow rates.
 - d. Verify building pressurization.
 - e. Verify total exhaust air flow, and total outdoor air intake.
 7. Verification of the proper responses of monitoring and control system controllers and sensors shall be as follows:
 - a. For each controller or sensor, record the indicated monitoring and control system reading, and the test instrument reading.
 - b. If the initial test indicates that the test reading is outside of the control range of the installed device, the calibration of the installed device shall be checked and adjusted as required. The deficient device shall be re-tested and the results recorded on the checklist data sheet.

- b. The Commissioning Authority shall direct and witness the field verification of the final TAB report.

1. The Commissioning Authority shall select, at random, 10 percent of the report data for verification.
2. The TAB contractor shall be given sufficient advance notice of the date of field verification. However, they shall not be informed in advance of the data points to be verified. The TAB contractor must use the same instruments (by model and serial number) that were used when the original data were collected.
3. Failure of an item is defined as:
 - a. For all readings other than sound, a deviation of more than 10 percent.
 - b. For sound pressure readings, a deviation of 3 decibels. (Note: variations in background noise must be considered).
4. A failure of more than 10 percent of the selected items shall result in the rejection of the final TAB report.
- c. If deficiencies are identified during verification, the construction manager must be notified, and action taken to remedy the deficiency. The final tabulated checklist data sheets shall be reviewed by the Design Professional and the Commissioning Authority, to determine if verification is complete, and the operating system is functioning in accordance with the contract documents.

B. Functional Performance Testing

1. Scope of Functional Performance Testing
 - a. Functional performance tests shall determine if the HVAC system is providing the required cooling and heating services in accordance with the final design intent. They shall also determine the installed capacity of the cooling and heating plant, and heat transfer components. Following is a list of test examples:
 1. Determine capability of chilled water system to deliver chilled water at the design supply temperature, and required rate of flow.
 2. Determine capacity of electric heating system to deliver heating at the design temperature.
 3. Determine the ability of the HVAC unit to deliver the cooling and/or heating services to the distribution system, at the design supply air temperature, required static pressure, and proper outside air ventilation rate.
2. Submittals
 - a. Detailed procedures for each series of tests shall be submitted to the Commissioning Authority for review and acceptance. The procedures shall include samples of the data sheets that will be part of the reports.

3. Participants in Functional Performance Tests
 - a. Participants in the functional performance tests shall be the same as those listed in the verification tests.
4. Instrumentation
 - a. In addition to the instrumentation requirements detailed under verification, the Commissioning Authority may need to provide data acquisition equipment to record data for the complete range of testing.
5. Functional Performance Test Procedures
 - a. The Commissioning Authority shall supervise and direct all functional performance tests.
 - b. For each test, the Commissioning Authority shall install the measuring instruments and logging devices to record test data for the required test period. The instrumentation shall monitor and record all operating conditions to allow for complete evaluation of the test results.
 - c. Measurements will be required to allow for calculation of total capacity of the system for each mode of operation under test.
6. Documentation and Reporting Requirements
 - a. All measured data, data sheets, and a comprehensive summary, describing the operation of the HVAC system at the time of testing shall be submitted to the Commissioning Authority.
 - b. A preliminary functional performance test report shall be prepared by the Commissioning Authority and submitted to the Design Professional for review. Any identified deficiencies need to be evaluated by the Design Professional and Construction Manager to determine if they are part of the contractor's or sub-contractor's contractual obligations. Construction deficiencies shall be corrected by the responsible contractor(s), and the specific functional performance test repeated.
 - c. If it is determined that the HVAC system is constructed in accordance with the contract documents, and the performance deficiencies are not part of the contract documents, the owner must decide whether any required modifications needed to bring the performance of the HVAC system up to the finalized design intent shall be implemented, or if the test shall be accepted as submitted. If corrective work is performed, the owner shall determine if a portion or all required functional performance tests should be repeated, and a revised report submitted.

3.07 Operating and Maintenance Manual:

- A. The operating and maintenance manual shall consist of a sturdy binder with 8-1/2" X 11" sheets containing the following major sections:
 1. System Descriptions:
 - a. Each major system shall be described, typewritten, in general terms, including major com-

ponents, interconnections, theory of operation, theory of controls, unusual features and major safety precautions. This information should correlate with information provided in the manufacturers' instructions book. This section shall include, but not be limited to, the following data:

1. Detailed description of each system and each of its components showing piping, valves, controls, and other components, with diagrams and illustrations where applicable.
 2. Wiring and control diagrams with data to explain detailed operation and control of each component.
 3. Control sequences describing start-up, all modes of operation, and shut down.
 4. Corrected shop drawings.
 5. Approved product data including all performance curves and rating data.
 6. Copies of approved certifications and laboratory test reports (where applicable).
 7. Copies of warranties.
 - b. System diagrams, described in 3.07 B2 following, shall be incorporated in the appropriate systems descriptions. These should be reduced in size or folded to usefully fit into the manual.
2. Operating Instructions:
 - a. Condensed, typewritten, suitable for posting, instructions shall be provided for each major piece of equipment. Where more than one (1) common unit is installed, one instruction is adequate. The instructions shall provide procedures for:
 1. Starting up the equipment/system.
 2. Shutting down the equipment/system.
 3. Operating the equipment in emergency or unusual conditions.
 4. Safety precautions.
 5. Trouble shooting suggestions.
 6. Other pertinent data applicable to the operation of particular systems or equipment.
 - b. The instructions shall be suitable for posting adjacent to the equipment concerned.
The Contractor shall provide instructions for:
 1. Electric heating equipment
 2. Hydronic distribution systems, including pumps.
 3. Air handling units and exhaust fans.
 4. DDC control systems.
 5. Fan powered mixing boxes.
 6. Emergency generating plants.
 7. Domestic water pumps.
 8. Variable frequency drive.
 9. Other specialized or uncommon equipment.
 3. Ongoing and Preventive Maintenance:
 - a. Condensed, typewritten procedures for recommended ongoing and preventive maintenance actions shall be provided for each category of equipment/system listed in 3.07 A2 above.

This information shall include, but not be limited to the following:

1. Maintenance and overhaul instructions.
 2. Lubricating schedule including type, grade, temperature, and frequency range.
 3. Parts list, including source of supply and recommended spare parts.
 4. Name, address, and 24 hour telephone number of each subcontractor who installed equipment and systems, and local representative for each type of system.
 5. Other pertinent data applicable to the maintenance of particular systems or equipment.
 - b. These recommended preventive maintenance actions shall be categorized by the following recommended frequencies:
 1. Weekly
 2. Monthly
 3. Quarterly
 4. Semi-Annual
 5. Annual
 6. Other
- B. Posted Operating Instructions and Diagrams:
1. Operating Instructions:
 - a. Copies of operating instructions provided in the operating manual (3.07 A above) shall be posted in the near vicinity of each piece of applicable equipment. The instructions shall be mounted neatly in frames under Plexiglas, where they can be easily read by operating personnel. Instructions mounted outdoors shall be suitably protected from weather.
 2. Posted Systems Diagrams:
 - a. Simplified one (1) line diagrams of the systems listed shall be developed and transcribed on transparent "D" sized erasable sepia film and posted neatly under Plexiglas in the main or most appropriate equipment room for easy reference by operating and maintenance personnel. These drawings shall be done in a professional manner which is acceptable to the Maintenance Division staff. The diagrams shall show each component including all valves installed in the system, with name and identifying number. If space does not permit valve numbers on the diagrams, valve charts shall be provided. Explanatory notes, where needed, shall be provided.
 1. HVAC controls diagram
 2. Hydronic distribution system.
 3. Electric heating system.
 4. Air handling/ventilation system.
 5. Domestic water system.
 6. Emergency power generation.
 7. Other systems as applicable.
 - b. These diagrams shall be suitable for reduction in size and use in the operating manual system descriptions previously covered.

3.08 Operating and Maintenance Training:

- A. The Mechanical Contractor, and appropriate sub-contractors, shall provide comprehensive operating and maintenance instruction on building systems prior to delivery. The instruction shall include classroom instruction delivered by competent instructors based upon the contents of the operating manual. Emphasis shall be placed upon overall systems diagrams and descriptions, and why systems were designed as they were. This overall systems instruction shall preferably be delivered by the consulting engineers. The classroom instruction shall also include detailed equipment instruction by qualified manufacturer representatives for all equipment listed in 2.04 A for which operating instructions are provided. The manufacturer representative training shall emphasize operating instructions, and preventive maintenance as described in the operating manual. At a minimum, the training sessions shall cover the following items:
1. Types of installed systems
 2. Theory of operation
 - a. Design intent
 - b. Occupied vs. unoccupied or partial occupancy
 - c. Seasonal modes of operation
 - d. Emergency conditions and procedures
 - e. Comfort conditions
 - f. Indoor air quality
 - g. Energy efficiency
 - h. Other issues important to facility operation.
 3. System operations.
 4. Use of control system
 - a. Sequence of operation
 - b. Problem indicators
 - c. Diagnostics
 - d. Corrective actions.
 5. Service, maintenance, diagnostics and repair.
 6. Use of reports and logs.
 7. Troubleshooting, investigation of malfunctions, and determining reasons for the problem.
- B. Each classroom training period shall be followed by an inspection, explanation and demonstration of the system concerned by the instructors. All equipment listed in 3.07 A shall be started up and shut down, with the exception of sprinkler systems.
- C. The contractor shall be responsible for organizing, arranging, and delivering this instruction in an efficient and effective manner on a schedule agreeable to the owner.
- D. The contractor shall provide, at or before substantial completion, a proposed agenda and schedule of the above training for approval by the Commissioning Authority and the Owner.

A7. Acceptance-Phase Procedures

A7.1 Overview

A description of the acceptance-phase procedures is critical to the commissioning process. This discussion is applicable to a typical comprehensive commissioning process. Verification testing will determine if the HVAC system is operating in accordance with contract documents. Functional

performance testing (FPT) will determine if the HVAC system is performing in accordance with the finalized design intent (as revised in the design process and approved by the owner). These procedures may start once the mechanical contractor has notified the construction manager that the HVAC system installation has been completed and the design professional has accepted the TAB report from the testing, adjusting, and balancing contractor.

Typically verification tests are directed and witnessed by the commissioning authority. If deficiencies are identified during verification, the construction manager must be notified and action taken to remedy the deficiency. Once verification is completed and the operating system is functioning in accordance with the contract documents, the commissioning authority can issue the verification report to the owner and HVAC design professional for review. Once satisfied with the completion of verification, the HVAC design professional can issue the Certificate of Readiness, allowing functional performance testing to begin. The commissioning authority should supervise and direct the functional performance tests. Performance deficiencies (as opposed to construction punch list deficiencies), at the owner's discretion, should be corrected and the tests repeated. The verification test checklists and the data and evaluation of the final FPT tests should be made part of the commissioning authority's commissioning report.

Verification

Verification is composed of a full range of checks and tests to determine that all components, equipment, systems, and interfaces between systems (e.g., emergency, fire, and life safety) operate in accordance with contract documents. This includes all operating modes, interlocks, control responses, and specific responses to abnormal or emergency conditions. Verification of the proper operation of the control system also includes verifying the interface of the control system with the TAB criteria and the response of monitoring and control system controllers and sensors. Verification of operating modes, etc., can be done concurrently with controllers and sensors. Verification will also validate the test and balance (TAB) report.

Functional Performance Testing

FPT will determine if the HVAC system is providing the required cooling, ventilating, and heating services in accordance with the finalized design intent. FPT will also determine the as-built installed capacity of the cooling and heating plant and the heat transfer components.

In most cases, FPT will be completed at less than full-load conditions in the heating, ventilating, and cooling modes. For this reason, specifications must include the requirements for part-load performance data to be submitted by the manufacturers of all heat transfer equipment. This also applies to system curves for pumps that operate with variable-frequency drives (VFD) and fans at partial loads.

A preliminary FPT report will be prepared by the commissioning authority and submitted to the design professional for review. Any identified performance deficiencies need to be evaluated by the design professional and the construction

manager to determine the cause and if they are part of the contractor's contractual obligations. It may not be possible to correct these deficiencies without major modifications to the HVAC system. If it is determined that the HVAC system is constructed in accordance with contract documents and that the performance deficiencies are not part of the contract documents, the owner must decide whether any required modifications to bring the performance of the HVAC system up to the finalized design intent will be implemented or if the FPT will be accepted as submitted. If corrective work is performed, a portion of or all of the FPT should be repeated and a revised report submitted.

A7.2 Sample Acceptance-Phase Procedures

This example contains test procedures to be included in the updated Commissioning Plan prepared during the construction phase. This list can be expanded or modified as needed to suit the specifics of the project. Comments are in italics.

A. Verification Tests

1. Scope of Verification Tests.

- a. Operating tests and checks to verify that all components, equipment, systems, subsystems, and interfaces between systems operate in accordance with contract documents. Tests to include all operating modes, all specified responses, all interlocks, all control responses, all specific responses to abnormal or emergency conditions, and verification of the proper response of the monitoring and control system controllers and sensors.
- b. Verify the validity of the test and balance (TAB) report.

2. Participants in Verification Tests.

Note: The list included here is not intended to be complete. The participants will be determined by the type of HVAC system to be tested and the requirements of the facility.

The commissioning authority (C.A.) will be responsible for preparing the scope of these tests. The C.A. will schedule the tests and assemble the commissioning team members who will participate. The participating contractors, manufacturers, suppliers, etc., will include all costs to do work involved in these tests in their proposal. Following is a list of tasks and supporting information that will be required.

- a. Controls contractor- Provide services of a controls engineer who is familiar with the details of this project. Provide details of the control system, schematics, and a narrative description of the controls sequence of operation at the job site at the time of the tests.
- b. Testing contractor- Provide services of an experienced testing technician and instrumentation required for each of the tests.
- c. Electrical contractor- Provide a foreman electrician who is familiar with the electrical interlocks, interfaces with emergency power supply, interfaces with alarm and life safety systems. Provide the contract drawings and all as-built schematics of subsystems, interfaces, and interlocks at the job site at the time of the tests.

- d. Mechanical contractor- Provide the services of an engineer and service personnel who are familiar with the construction and operation of this system. Make available the contract plans, shop drawings, and equipment cut sheets of all equipment that are involved at the job site at the time of the tests.

3. Verification Documentation Requirements of the Testing Contractor.

In addition to the contract documents detailed in the requirements for each of the participants, the following documentation will be required for complete execution of the tests.

- a. Provide checklists for each component, equipment, system, and subsystem, interface, interlock, etc. Each item to be checked shall have a different entry line with space provided for comments. Separate checklists shall be prepared for each mode of operation. Provide space for indicating whether the mode under test responded as required or not. Provide additional space for the test technician and the C.A. to initial each item.
- b. Data sheets used in the verification of the proper operation of the control system will include each controller to be verified, the system it serves, the service it provides, and its location. For each controller, provide space for recording the readout of the controller, the reading at the controller's sensor(s), and comments. Provide space for the C.A. to sign off each data sheet.
- c. Data sheets used in verification of the validity of the TAB report shall be similar to the TAB data sheets used in the TAB report, except an additional column shall be provided to record the verification test data. Provide space for the C.A. to sign off each data sheet.
- d. All test procedures and data sheets shall be submitted to the design professional for review and acceptance.

4. Instrumentation.

The testing contractor shall furnish all measurement instrumentation for the verification tests. All instruments will be calibrated within the six-month period prior to the verification tests. Diagnostic equipment is to be provided by the appropriate contractor.

Note: If the testing contractor is also the TAB contractor, then the same instruments that were used in the TAB procedures will be used in these tests. However, the same requirements for calibration will still apply.

- a. To be provided by the testing contractor:
 - 1) Airflow-measuring equipment
 - a) Flow hood meter capable of measuring the airflow rates at diffusers and registers.
 - b) Pitot tubes (sizes as required).
 - c) Differential pressure instruments capable of accurate measurements from as low as 0.0005 in. w.c.
 - d) Static pressure-sensing tips and any required sensing devices.
 - e) Smoke tubes, smoke candles, etc., as required to demonstrate patterns of air distribution.
 - 2) Water flow measurement equipment

- a) Differential pressure instruments (ranges as required).
- b) Mass and velocity flowmeters (capacities and type as required).
- c) Test quality pressure gauges.

3) Temperature and relative humidity measurement equipment

- a) Outside ambient, room, and duct air temperature and RH sensors or transmitters.
- b) Liquid insertion or surface temperature sensors or transmitters.
- c) Dew-point temperature sensors or transmitters.

4) Electric demand measurement equipment

- a) Ammeter, voltmeter, and kW recorders.
- b) kW electric demand meter or transmitter system.
- c) Power factor meter or transmitter.

5) Recorders or data loggers, as required, may be utilized to collect the measured data provided by the instruments above.

b. To be provided by the controls contractor:

- 1) Access to control system to compare data and make adjustments as required.

c. To be provided by the electrical contractor:

- 1) Continuity testing meter or other related diagnostic equipment.

d. To be provided by the mechanical contractor:

- 1) All tools and devices to make adjustments as required.

5. Verification Procedures.

a. Operating tests and checks

- 1) The C.A. will direct and witness verification operating tests and checks.
- 2) Set the system equipment, e.g. chiller, boiler, HVAC unit, exhaust blowers, into the operating mode to be tested, e.g. normal shutdown, normal-auto position, normal-manual position, unoccupied cycle, emergency power, and alarm conditions.
- 3) Each operating cycle shall be tested after it has been running for a period of (no.) hours and it is operating in a steady-state condition.
- 4) The C.A. and the testing contractor's technician will inspect and verify the position of each device and interlock that is identified on the checklist. Each item shall be signed off as acceptable (yes) or failed (no).
- 5) This test will be repeated for each operating cycle that applies to the HVAC system being tested.
- 6) Operating checks shall include all safety cutouts, alarms, and interlocks with smoke control and life safety systems during all modes of operation of the HVAC system
- 7) If, during a test, an operating deficiency is observed, appropriate comments shall be added to the checklist data sheet.
- 8) Verification of the interface of the monitoring and control system and the TAB criteria shall include the following:

- a) Verify flow rates for air and water systems (e.g., supply, return, and exhaust) in all modes of operation of the HVAC system.
 - b) Verify operation of the terminal units in all modes of operation.
 - c) Verify minimum outdoor air intake in all modes of operation and at minimum and maximum total airflow rates.
 - d) Verify building pressurization.
 - e) Verify total exhaust airflow and total outdoor air intake (OAD).
 - f) Verify operation of the IAQ monitoring system.
 - g) Failure to pass the verification test is as defined in "Verification of the Final TAB Report" below.
 - h) The deficiency shall be corrected by the responsible contractor(s) and the condition retested and results recorded on the checklist data sheet.
- 9) To verify the proper response of monitoring and control system controllers and sensors:
- a) For each controller or sensor, record the indicated monitoring and control system reading and the test instrument reading.
 - b) If the initial test indicates that the test reading is outside the control range of the installed device, the calibration of the installed device shall be checked and adjusted as required. The deficient device shall be retested and the results recorded on the checklist data sheet.
- b. Verification of the Final TAB report
- 1) The C.A. will direct and witness the field verification of the final TAB report.
 - 2) The C.A. will select at random a percentage of the report data for verification. Report data are defined as the air velocity at a specific outlet, air or water flow rate, indicated differential pressure, electrical or sound measurement, or any other measurement that is applicable.
 - 3) If the testing contractor is also the test and balance contractor, he/she shall be given sufficient advance notice of the date of field verification. However, he/she shall not be informed in advance of the data points to be verified. The test and balance contractor must use the same instruments (by model and serial number) that were used when the original data were determined.
 - 4) Failure of an item is defined as the following:
 - a) For all readings other than sound, a deviation of more than 10%.
 - b) For sound pressure readings, a deviation of 3 decibels. Variations in background noise must be considered.
 - 5) A failure of more than 10% of the selected items shall result in the failure of acceptance of the final TAB report.
- 6) Failure of the final TAB report shall require the testing and balancing contractor to complete the following work at no additional cost:
 - a) Any system failing the verification procedure must be rebalanced.
 - b) New total system TAB reports must be provided.
 - c) Field verification of the new TAB report must be performed.
 - c. If deficiencies are identified during verification, the construction manager must be notified and action taken to remedy the deficiency. The final tabulated checklist data sheets shall be reviewed by the HVAC design professional and the C.A. to determine if verification is completed and the operating system is functioning in accordance with the contract documents. Once verification is completed, the C.A. shall provide a verification report to the owner and HVAC design professional for review. Once satisfied with the completion of verification, the HVAC design professional shall issue the Certificate of Readiness allowing functional performance testing to begin.
- B. Functional Performance Testing (FPT)**
1. Scope of Functional Performance Testing
- a. FPT will determine if the HVAC system is providing the required cooling and heating services in accordance with the finalized design intent. It will also determine the as-built installed capacity of the cooling and heating plant and the heat transfer components.
 - b. Specific Tests to Be Conducted:

(The following is a representative list of test examples)

 - 1. Determine capability of chiller and associated primary and secondary equipment to deliver chilled water at the design supply temperature and required rate of flow.
 - 2. Determine capacity of boiler (or other heating source) and associated equipment to deliver heating service at the design temperature, pressure, and rate of flow.
 - 3. Determine the ability of the HVAC unit to deliver the cooling and/or heating services to the distribution system at the design supply air temperature, required static pressure, and proportion of outside air ventilation rate.
 - 4. Individual room tests will be conducted in (*specify*) rooms for a period of (*no.*) days to verify the capability of the HVAC system to provide the design conditions at maximum cooling and heating loads.
2. Submittals
- Detailed procedures for each series of tests shall be submitted to the C.A. for review and acceptance by the design professional. The procedures shall include samples of the data sheets that will be part of the reports.
3. Participants in FPT
- (Please see participants in verification tests in section A.2 above)*

4. Instrumentation

In addition to the instrumentation requirements detailed in verification, the testing contractor will provide data-acquisition equipment to record the data for the complete range of testing. (*Please see instrumentation, section A.4 above.*)

5. FPT Procedures

- a. The C.A. will supervise and direct FPT.
- b. For each test, the testing contractor will install the measuring instruments and logging devices to record the test data for the required test period. The instrumentation shall meter and record all operating conditions to allow for complete evaluation of the test results.
- c. Measurements will be required to allow for calculation of total capacity of the system for each mode of operation under test. If a cooling test is conducted during the heating season, it will be repeated during the next cooling season.
- d. For individual room cooling tests, the testing contractor shall provide electric room heaters at a (*specify*) schedule of loads.

6. FPT Documentation and Reporting Requirements

- a. All measured data, data sheets, and a comprehensive summary describing the operation of the HVAC system at the time of the test will be submitted to the C.A. by the testing contractor. If there are deviations in performance from contract documents or the finalized design intent, a description and an analysis shall be included.
- b. A preliminary FPT report will be prepared by the C.A. and submitted to the design professional for review. Any identified performance deficiencies need to be evaluated by the design professional and the construction manager to determine if they are part of the contractor's or subcontractor's contractual obligations. Construction deficiencies will be corrected by the responsible contractor(s) and the specific FPT repeated.
- c. If it is determined that the HVAC system is constructed in accordance with contract documents and that the performance deficiencies are not part of the contract documents, the owner must decide whether any required modifications to bring the performance of the HVAC system up to the finalized design intent will be implemented or if the FPT will be accepted as submitted. If corrective work is performed, the owner will determine if a portion or all of the functional performance testing should be repeated and a revised report submitted.

(This annex is not part of this guideline but is provided for information purposes only.)

ANNEX B

COMMISSIONING AN HVAC SYSTEM: COSTS AND BENEFITS OF THE PROCESS

B1. OVERVIEW

To date, commissioning has been incorrectly viewed as component checkout and start-up. In reality, it is the process

of producing a system that performs as the owner intended. To facilitate this task, an additional scope of work as defined in this guideline, which is not now part of HVAC system construction, must be undertaken.

There are numerous contractual obligations identified in the commissioning process. These obligations begin as early as the program phase and continue until final acceptance of the HVAC system. This annex discusses the potential benefits and where they will accrue, quantifying these benefits by providing evidence of potential costs and savings.

B2. DISCUSSION OF NEW COST ITEMS

Ultimately, the owner of the facility will determine the extent of the commissioning process and who will be responsible for each phase of work. The intent here is to outline the scope of work that represents new cost items rather than to assign responsibilities for each task. The cost of the commissioning process should be considered as a part of the project budget.

Design Professional

In addition to the design professional's typical scope of work, including the preparation of design drawings and specifications, the commissioning process often requires additional specifications. They include specifications for the following:

1. Functional performance and acceptance testing.
2. Commissioning Plan.
3. Commissioning documentation.
4. Systems Manual.
5. Comprehensive training program for operating personnel.
6. Comprehensive training program for maintenance personnel.

The design professional may also review the commissioning authority's Commissioning Plan at the various phases of the process.

Commissioning Authority

The concept of a commissioning authority, as defined in this guideline, is new to the process of constructing an HVAC system and therefore represents a complete addition in cost. For details of responsibilities, refer to section 2 of Annex A, statement of "Responsibilities of the Participants."

Acceptance Tests

The concept of acceptance testing as specified in the commissioning process is not typically part of the current construction process for an HVAC system. It will incur an increase in cost. Refer to Annex A7, Acceptance-Phase Procedures.

B3. DISCUSSION OF BENEFITS

For convenience and clarity, benefits will be discussed as they relate to major participants in the commissioning process: the design professional, the contractor, and the owner.

Benefits to the Design Professional

Potential benefits include:

- HVAC system will perform in accordance with the owner's requirements.

- Reduced risk exposure.
- Improved knowledge base for use in future designs and installation.
- Benefit of other participants' input, leading to the most cost-effective design and operation.
- Reduced number of interference drawings during construction due to improved communication and coordination throughout the project.

Benefits to the Contractor

Potential benefits include:

- Improved planning and coordination through the implementation of the Commissioning Plan.
- Improved coordination between different trades and reduced likelihood of site interference drawings required of contractors throughout the project.
- Reduced number of deficiencies at substantial completion.
- Reduced number of call-backs.
- Reduced number of calls for operational guidance due to participation in training programs for operations personnel and maintenance personnel.

Benefits to the Owner

Potential benefits include:

- Improved operator knowledge of how the system should operate because of early inclusion in the commissioning process.
- Reduced training requirements due to continuously updated documentation of how systems should operate and be maintained; personnel will only need to be trained with regard to changes.
- System performance is in accordance with owner's program.
- Systems Manual provides an easy reference document for equipment and system operation and maintenance.
- Reduced downtime due to better diagnosis of equipment and system failure.
- Improved ability to provide accurate information to occupants regarding maintenance of environmental conditions in the occupied space throughout the year.
- Lower operating costs due to improved operational techniques.
- Benefits to building occupants, including greater worker productivity, reduced complaints due to indoor air quality, and reduced incidence of absenteeism.

(This annex is not part of this guideline but is provided for information purposes only.)

ANNEX C

INDOOR AIR QUALITY AND HVAC COMMISSIONING

C1. INTRODUCTION

The increasing demand for acceptable indoor air quality (IAQ) is a factor that should be considered in the design, construction, and commissioning of all facilities. The performance of the HVAC system has a significant effect on indoor air quality. The HVAC system influences the following aspects of IAQ:

struction, and commissioning of all facilities. The performance of the HVAC system has a significant effect on indoor air quality. The HVAC system influences the following aspects of IAQ:

- Outdoor air ventilation rate
- Ventilation effectiveness
- Air change rates
- Building pressurization
- Comfort conditions
- Contaminant removal and control

The acceptance tests and the functional performance tests, together with the documentation requirements of the commissioning process, will allow each of these items to be documented and verified.

This annex addresses factors to be considered in the commissioning process to establish and maintain satisfactory IAQ. It is intended for use by all parties involved in the commissioning of an HVAC system and has been organized to correspond to each phase of the commissioning process as outlined in the guideline. Specifically, it discusses how the HVAC system can be utilized to manage or contain sources of contamination.

It must be noted that some of the design and construction decisions that affect IAQ are not the responsibility of the HVAC design professional or the commissioning authority nor will they necessarily be able to accurately describe the sources or levels of contaminants present during the design and construction phases. Some items included in this annex may be more appropriately applied to whole-building commissioning.

The performance of the HVAC system is not the only factor that affects IAQ. Other building components and aspects can affect the IAQ as well. A partial list of such items includes:

- Floor covering
- Wall covering
- Adhesives
- Partitions and ceiling
- Furniture
- Insulation and fireproofing materials
- Sealants, paints, varnishes, and other finish materials
- Office equipment
- Maintenance performance
- Janitorial practices
- Pest management
- Building use and materials brought in (e.g., food service, plants)
- Building remodeling
- Mold and/or fungal growth outside of HVAC system

C2. PROGRAM PHASE

Identify and document indoor air quality requirements in accordance with the initial design intent of the owner. This could include standards, ventilation, and levels of ventilation effectiveness that are to be maintained. Appropriate standards should be included such as *ANSI/ASHRAE Standard 62-1989, Ventilation for Acceptable Air Quality* and *ANSI/ASHRAE*

Standard 55-1992, Thermal Environmental Conditions for Human Occupancy, in addition to applicable building codes.

Review projected occupant activity, density, and locations on which heating, ventilating, and air-conditioning (HVAC) design was based. Attention should be paid to special use areas such as kitchens/break areas smoking lounges, photocopy/print rooms, janitorial rooms, material storage rooms, and meeting/conference rooms. Identify the need for exhaust systems to serve these special use areas and all other process areas that contain contaminant-generating equipment or systems as required.

Identify the outdoor sources of pollutants in the vicinity of the building site, such as discharge of exhaust systems, cooling towers of neighboring buildings, smoke stacks, and existing or proposed parking garages. Prevailing winds should also be taken into account. The quality of the outdoor air at the building site may require special treatment of the outdoor air for ventilation purposes. This may also include an assessment of soil and groundwater, which may interact with the building's ventilation and building structure.

Identify indoor air pollution sources that need supplemental exhaust. Potential sources include photocopiers, printing operations, and smoking lounges.

C3. DESIGN PHASE

Ensure that the indoor air quality goals established in the program phase are included in the design and are well documented in the design intent. The following tasks should be completed, as applicable, during the design phase:

1. Establish the outdoor air intake requirements for each area of the building based on the projected occupancy.
2. Establish procedures for documenting ventilation throughout the occupied areas served by the HVAC system.
3. Establish exhaust airflow rates and systems required to serve process areas, food service areas, break areas, and smoking lounges.
4. Review design intent under all projected modes of operation and anticipated outdoor conditions, such as minimum and maximum outdoor temperatures, humidity, and other extreme outdoor conditions. Specific attention should be given to ventilation rates and control, distribution of outside air, and temperature and humidity control during all projected operation modes, including part-load conditions and temporary ventilation regimes during construction and initial occupancy.
5. Review orientation of air intakes and exhausts with respect to short-circuiting and local pollution sources such as garages, loading docks, and cooling towers.
6. Assess configuration of office partitions with respect to ventilation effectiveness.
7. Review provisions of supplemental exhaust from known indoor pollution sources.
8. Review choice of filtration type and design, materials, and location within the ventilation system. This should incorporate placement of air filtration systems based on outdoor air conditions and desired indoor contaminant concentrations.

9. Review specification of HVAC materials according to susceptibility to airflow erosion, corrosion, and microbial contamination.
10. Review design of air supply system components such as condensate trays, humidifiers, water baffles, mist eliminators, and cooling towers to control the presence of free water and minimize microbial contamination.
11. Establish the availability of access doors and/or inspection ports to all chambers and components of air-handling system plenums. Verify that access doors on air-handling units are adequate to allow proper cleaning of both sides of coils, condensate pans, and/or humidifier reservoirs.
12. Review specification and placement of HVAC insulation materials with respect to potential microbial contamination.
13. Examine manufacturer's safety data sheets (MSDS) for products specified in contract documents that may be suspected contributors to indoor pollutants, including carpets, flooring, fabrics, adhesives, wall coverings, partitions, and ceilings; insulating and fireproofing materials; sealants on windows, walls, and floors; use of preservatives, paints, varnishes, and other finish materials.
14. Request that manufacturers provide information on curing, drying, and airing procedures for their products to minimize subsequent emission rates. Manufacturers can be asked the following questions:
 - a. What information does the supplier have about emissions of volatile organic compounds from the product after manufacture? What chemical content labeling is included with the product?
 - b. What steps, both in manufacture and post-construction treatment, does the manufacturer take to reduce emissions from the product before the product is installed in the building?
 - c. Is it possible for the manufacturer to air out the product before installation? If so, for how long and under what conditions?
15. Review installation instructions for proposed adhesive materials used for installing sealing compounds, wall and carpet adhesives, paints, varnishes, etc., ensuring minimum use consistent with proper application.

C4. CONSTRUCTION PHASE

Implementation of good IAQ design practices must be critically supervised during the construction phase. Suggested items to be addressed during this phase include the following:

1. Verify that HVAC equipment and related materials are delivered and installed as specified in the construction documents. All MSDS, including emission rate data, should be submitted in the construction documents. Document any changes in materials.
2. Review installation of system components, such as condensate pans and humidity control equipment to control free water within the air-handling system.
3. Verify access to all critical components of the air supply systems that will require future cleaning and servicing.
4. Verify proper and careful installation of all HVAC insulation materials.

5. Monitor temporary operation of the ventilation and filtration systems during periods of construction such as interior finishing. This may require increased ventilation rates and schedules and the use of items such as temporary installation of prefilters, unitary conditioning/filtering units, and removable windows. Ensure that construction filters are used and maintained whenever ventilation systems are operated during construction.
6. When the building is partially occupied during construction, operate the HVAC system to isolate occupied areas of the building from areas where construction is occurring. For example, this could be achieved by maintaining a relative positive pressure in occupied zones and diverting return air from the construction zones directly outdoors.
7. Operation of installed ventilation, exhaust, and space comfort components and units prior to completion of automatic system controls must be according to construction documents. This should prevent damage to equipment and IAQ degradation of occupied spaces from contaminants, humidity, or other impacts on the building.

C5. ACCEPTANCE PHASE

The acceptance phase of the commissioning process includes the functional performance tests and the verification tests of the TAB report and the performance of the automatic control systems.

Many of these tests and checks facilitate the determination of the IAQ within the facility. Consider conducting the following:

1. Examine and verify that all HVAC system internals and filters are clean of dust and debris and ready for operation.
2. Verify the minimum rates of outdoor air intake to each HVAC air-handling system. It should be verified that this rate remains constant throughout each mode of operation at all thermal loads on the HVAC system.
3. Verify that the ventilation systems are maintaining the specified building pressurization.
4. Verify that the air distribution systems are providing the required ventilation effectiveness throughout the occupied areas of the facility.
5. Verify the performance of the exhaust systems with regard to their effect on IAQ.
6. Verify the performance of the automatic control systems with regard to ventilation and comfort control.
7. Test and verify effective operation of those components of the air-handling systems that use free water, including humidification control equipment. Proper drainage of water around the building, especially in the vicinity of all outside air intakes, should be verified.
8. Examine all insulating materials for integrity and proper installation.
9. Review test and balance reports and compare to specifications. A spot check of ventilation rates and temperature and humidity control is recommended.
10. Conduct air quality testing as required in the Owner's Program.

C6. POST-ACCEPTANCE PHASE

The post-acceptance phase of the commissioning process will continue throughout the life of the facility. During the

guarantee period, additional functional performance tests may need to be conducted and repeated for different seasonal conditions. For these tests, utilize the procedures detailed in clause 9, covering the acceptance phase of this guideline.

After the guarantee period is completed, it is important to continue to verify that acceptable IAQ is maintained during all operating modes and after all future facility modifications. Areas of concern include:

1. Operating and maintenance procedures, which should include frequent inspections and verification of the following:
 - a. Avoidance of unnecessary sources of inside/outside air contaminants
 - b. Specified outdoor ventilation rates
 - c. Air filtration effectiveness
 - d. Area ventilation effectiveness
 - e. Condition of mechanical equipment
 - f. Operation of the automatic control systems
 - g. Operation of exhaust systems
2. Procedures used during any renovations of the facility or HVAC system.

(This annex is not part of this guideline but is provided for information purposes only.)

ANNEX D

ENERGY-EFFICIENCY REFERENCE INFORMATION

This annex is added as a guide for projects where the Owner's Program includes or emphasizes specific energy requirements.

Even when the owner's program does not include specific energy requirements, the program-phase Commissioning Plan should address general energy performance criteria to clarify the energy-efficiency expectations of the building or project. This may include minimum requirements of local energy-efficiency codes or requirements exceeding minimum codes where high energy efficiency is the best option for the project.

ASHRAE/IES Standard 90.1-1989 and ANSI/ASHRAE Standard 90.2-1993 were used as references in the preparation of this annex. The purpose of this annex is to provide guidance for the commissioning team to achieve an actual installed HVAC system that meets the owner's functional and operational requirements in a cost-effective, energy-efficient manner.

In a functioning, occupied building, all building systems interact, and the performance of each building system affects the performance of others. Therefore, information on all building systems are included in this annex as a reference for the owner, design professionals, construction manager, and commissioning authority as they develop the design intent, basis of design, and construction documents. In the start-up and operational phases of the commissioning process, it may be necessary to adjust controls, operating setpoints, and HVAC system design performance to reflect actual construction changes in other building systems. The final result is to

achieve a whole building, including the HVAC system, that is energy efficient.

D1. Program Development Phase

Owner's Requirements. The Owner's Program will establish the owners' needs and criteria for energy efficiency. This may be given as a defined list of requirements. For an owner with a large facility or a number of facilities, this may include a list such as the following.

1. The envelope, excluding glass/doors, shall have a U-value of 0.07 (Btu/ft²/°F) (0.040 (mW/m²)/°C).
2. The chiller shall have an ARI-rated efficiency of 0.68 kW/ton (5.17 COP).
3. The glass shall have a U-value of 0.38 (Btu/ft²/°F) (0.22 (mW/m²)/°C), with low infiltration.
4. The transport energy shall be less than 0.34 W/ft² (3.66 W/m²) at peak load.
5. The annual energy usage shall be less than 62,000 (Btu/ft²)/yr (704 (MJ/m²)/yr).
6. The lighting load shall be less than 0.94 W/ft² (10.1 W/m²).
7. The energy management system shall have capabilities for optimization through the DDC system and shall record energy usage by function on an hourly basis. Energy management control shall not compromise the building indoor air quality requirements.

This is a guide to help owners define their program needs. The following list is given to suggest further general ways in which owners can express their needs. Guidance has been provided for a variety of building types and project scopes. These will allow the design professional to develop design concepts that will allow the maximum options for meeting the owner's needs.

1. Achieve maximum energy efficiency within the current construction budget.
2. Facility (or HVAC system if an add-on or replacement) shall be 10% more efficient than the last building (applicable to organizations that construct a number of similar or identical commercial or industrial facilities).
3. All energy-efficiency design measures that have a simple payback of five years or less should be evaluated and presented to the owner and the assigned O&M staff for consideration.
4. All energy-efficiency design measures that have a life-cycle cost effectiveness of 10 years should be evaluated and presented to the owner and the assigned O&M staff for consideration.
5. It is desirable to have an energy-award-winning facility such as those recognized by the ASHRAE annual award program.
6. It is a goal of the owner to include innovative energy-efficiency options in this facility.
7. The HVAC system shall have demand-side management (DSM) and real-time electric rate energy use and cost management capabilities without compromising functional comfort and indoor environmental quality.
8. The HVAC system shall be a chilled-water storage system that has lower construction costs than a nonstorage chilled-water system, shall reduce annual energy usage by 10%, and reduce annual O&M costs by 40%.

9. It is a goal of the owner to have an HVAC system with ice thermal storage and cold air distribution (42° F to 47° F [5° C to 8° C] system supply air) with lower first cost, 20% annual energy cost reduction, and 25% annual O&M costs, with a meaningful improvement in comfort and indoor environmental quality.
10. It is the goal of the owner to have a dual-path HVAC system that will separately meet dehumidification and sensible loads. The dehumidification path shall not incur an energy penalty by using heat recovery, heat pipes, or thermal storage.
11. This facility should meet the minimum requirements of ASHRAE/IES Standard 90.1-1989.
12. The owner desires to have an energy-efficient facility, including owner-supplied equipment that will not sacrifice individual comfort control, whole-building indoor environmental quality, or the functional productivity of the facility.
13. The owner desires to have uniform temperature in all areas of the supermarket, with outdoor air distributed in proportion to typical occupancy, with space humidity controlled between 38% and 42% RH and with a 10% decrease in HVAC and refrigerated case energy usage and reduced annual maintenance costs of 25%.

Commissioning Authority Requirements. The initial design intent must be developed so that it meets the energy-efficiency requirements of the Owner's Program. When energy efficiency is a significant owner requirement, the commissioning authority - which may be developing or assisting in the development of the initial design intent - can be required to determine preliminary options available through contact with manufacturers and local utilities that will enhance the owner's system.

Design Professionals Requirements. The owner's energy requirements must be included in the refined design intent, the basis of design, and the HVAC and related building system and envelope design concepts.

Some guidance that may be helpful to the design team, including the basis of design criteria from ASHRAE/IES Standard 90.1 and ANSI/ASHRAE Standard 90.2, are:

1. Review the basis of design, paying special attention to energy performance criteria. Appropriate owner requirements and standards, such as ASHRAE/IES Standard 90.1, should be referenced.
2. Review successful energy-efficient projects.
3. Consider innovative systems that have been developed by manufacturers.
4. Review total wattage limits or W/ft² (W/m²) requirements for interior lighting systems.
5. Review watts per cubic feet of air per minute (watts per liter of air per second or W/ft² (W/m²) requirements for HVAC systems.
6. Review standard performance ratings for HVAC equipment, such as SEER, COP, AFUE, kW/ton, kWh/ton-h (kW/kW, MJ/MJ).
7. Review (Btu/ft²)/yr [(MJ/m²)/yr, (kWh/m²)/yr] requirements.
8. Review use of passive energy options and active solar or heat recovery and storage options.

9. Analyze future plans and the potential for central utility systems, including residential energy utility units (ground-source heat pump utility loop, cogeneration, grouped solar units, storage for multi-housing).
10. Establish the requirements for operations and maintenance that will impact energy efficiency.
11. Determine the relationship between occupancy schedules and energy use and develop energy reduction options, including local control and switching.

D2. Design-Phase Functions

General

Verify final design document calculations for occupancy levels, usage requirements, ventilation and other indoor environmental quality requirements, actual gross floor area, gross lighted area, gross wall area, gross fenestration area, gross roof area, area of skylights. Compare all building systems to the design intent.

Electrical System

1. Review design documents for the placement of check meters, if required, for lighting and receptacle outlets, HVAC systems and equipment, and other energy-consuming equipment.
2. Verify that calculations for the building electric load transformer(s) have been performed and that each transformer's full-, part-, and no-load losses comply with the criteria established in the design intent.
3. Verify that motor-sizing calculations have been performed and that the selected motors comply with criteria established in the design intent. Also verify that the specified motor efficiencies meet or exceed the criteria established in the design intent.
4. Review the requirements for, and application of, variable-frequency drives in terms of energy performance and their effect on other electrical equipment and the electrical system, including total harmonic distortion (THD).
5. Verify that requirements for start-up, performance testing, and operations and maintenance information for motors and electrical transformers are included in the design documents.

Lighting System

1. Verify that calculations, based on actual design documents, for the exterior and interior lighting systems have been performed and that the resulting lighting design complies with the design intent and that the resulting lighting design is used in electrical and HVAC system calculations.
2. Verify that any lighting controls included in calculations and/or in the design intent are included in the design documents.
3. Verify that requirements for start-up, performance testing, and operations and maintenance information for lighting luminaries and controls are included in the design documents.

Auxiliary Systems and Equipment

1. Verify that calculations, based on actual design documents, for auxiliary systems and equipment, such as transportation systems, freeze protection systems, food refrigeration systems, etc., have been performed and that the selected system complies with the design intent.
2. Verify that requirements for start-up, performance testing, and operations and maintenance information for auxiliary systems and equipment are included in the design documents.

Building Envelope

1. Verify that the selected building envelope and its components comply with the design intent and that the resulting building envelope design is used in other electrical and HVAC system calculations.
2. Verify that requirements for performance testing, leakage testing, and operations and maintenance information for the components of the building envelope are included in the design documents.

HVAC Systems and Equipment

1. Verify that building load calculations based on criteria stated in the basis of design have been performed and that the selected system and equipment comply with criteria established in the design intent.
2. Verify that equipment-sizing calculations have been performed and that the selected equipment sizes comply with criteria established in the design intent.
3. Verify that equipment and system controls required for the HVAC system to perform in accordance with the design intent have been included in the design documents.
4. Verify that requirements for start-up, performance testing, leakage testing, and operations and maintenance information for each HVAC system and each piece of HVAC equipment are included in the design documents.

Service Water-Heating Systems and Equipment

1. Verify that load calculations, based on criteria stated in the basis of design, have been performed and that the selected system and equipment comply with criteria established in the design intent.
2. Verify that equipment-sizing calculations have been performed and that selected equipment sizes comply with the criteria established in the design intent.
3. Verify that equipment and system controls required for the service water-heating system to perform in accordance with the design intent have been included in the design documents.
4. Verify that requirements for start-up, performance testing, leakage testing, and operations and maintenance information for each service water-heating system and each piece of equipment are included in the design documents.

Building Automation System

1. Verify that the capabilities and functions of the building automation system comply with the design intent.

2. Verify that electrical, lighting, HVAC, and service water-heating controls that are to be handled by the building automation system are included and consistent in the design documents.
3. Verify that requirements for start-up, performance testing, and operations and maintenance information for the building automation system and each component are included in the design documents.

D3. Construction-Phase Functions

1. Review change orders for compliance with design intent. Pay special attention to compliance with energy performance criteria established in the design intent.
2. Review change orders for compliance with the design documents and the impact that the change would have on the implementation of the Commissioning Plan.
3. Notify the design professional of all conflicts with performance criteria that develop and their effect on the Commissioning Plan.
4. The commissioning agent or owner should develop criteria for evaluating the knowledge and training competence

of the building operating staff for operating and maintaining the HVAC&R system and building to minimize energy usage plus understand measures that should not be implemented to save energy at the sacrifice of indoor environmental quality and functional productivity.

D4. Acceptance-Phase Functions

The acceptance phase and system start-up will require special attention to systems, components, and controls that impact the energy use in the building. This phase is key to operating efficiency. This is the phase of the project in which the maximum expertise is available (contractor, construction manager, control specialists, design team, manufacturers, owner [and the O&M staff], and commissioning agent) to identify energy-efficiency requirements and is the best opportunity to tune the systems, equipment, or controls to optimize the energy efficiency of the systems.

The Systems Manual needs to be evaluated to determine if guidance has been provided to achieve energy efficiency in the building while maintaining suitable IAQ.

**POLICY STATEMENT DEFINING ASHRAE'S CONCERN
FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES**

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effects on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

