

EPA Facilities Manual, Volume 2  
Architecture and Engineering Guidelines

Appendix B  
Commissioning Guidelines

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Supplier's support is required. The integrated commissioning process should have the distinct phases outlined below.

#### **B1.2.1 PRE-DESIGN PHASE**

The objectives of this phase are to document the owner's vision, requirements and future expectation for the facility, select the Commissioning Authority, document the initial design intent, and begin development of the Commissioning Plan. The roles and responsibilities of the owner, the Project Manager, design team, the Commissioning Authority and contractors must be defined for the commissioning process.

During pre-design, the commissioning team should include the EPA Project Manager, the Commissioning Authority, and the design team. The main commissioning tasks of the pre-design phase include:

- The EPA Project Manager should send out requests for qualifications for commissioning services, develop the scope of the commissioning effort, and select a Commissioning Authority and design team.
- The Commissioning Authority assembles the commissioning team and develops a draft design phase commissioning plan.
- The Commissioning Authority recommends the commissioning roles and scope for all members of the design and construction teams.
- The Commissioning Authority reviews the design intent for clarity and completeness.
- The Commissioning Authority delivers a draft design phase commissioning plan and comments on the Design Intent document.

#### **B1.2.2 DESIGN PHASE**

The goals of commissioning during the Design Phase are to ensure that the concepts for building systems developed during pre-design are included in subsequent design phases; that the design record document is updated; and that commissioning is adequately reflected in the contract documents. During the design phase, there are four primary commissioning activities: developing the Basis of Design and expanding design intent as necessary; performing commissioning-focused design reviews(s); expanding and modifying the Commissioning Plan to include the construction phase; and developing commissioning specifications for the construction phase. The main design phase commissioning tasks are outlined below:

- The Commissioning Authority updates the design phase commissioning plan started during pre-design phase.
- The design team develops Basis of Design documentation. The Commissioning Authority reviews this documentation for clarity, completeness, constructability and compliance with the EPA's design intent. In addition, all changes to the initial design intent must be documented, reviewed, and approved by the Commissioning Authority and EPA.
- The Commissioning Authority attends selected design team meetings and formally reviews and comments on the design at 15%, 35%, 65% and 100% stages of development. Potential system performance problems, energy-efficiency improvements, indoor environmental quality issues, operation and maintenance issues, and other issues should be addressed in these design reviews. The Commissioning Authority ensures that the design follows and meets the original design intent. The Commissioning Authority also makes recommendations to facilitate commissioning and improve building performance.
- The Commissioning Authority, in cooperation with the A/E team, develops detailed commissioning specifications to be included by the design team in the final contract document. The commissioning specifications detail the commissioning process and the scope of work for all participants including contractors and vendors. The specifications comprise commissioning-related requirements that will be the contractor's responsibility, including equipment installation and start-up, documentation, and functional testing.
- While writing the specifications for Commissioning, the Commissioning Authority develops a Preliminary Commissioning Plan. This plan becomes a scope of work that names actual components and systems in the design documents. The Commissioning Authority shall develop procedures for each of the systems to be commissioned. This interim plan should be incorporated into the specifications to give contractors the best possible idea of his part in the process. In addition, the

## Appendix B - Commissioning Guidelines

Commissioning Authority shall recommend enhanced language regarding training, documentation, installation, and system checkout for inclusion in non-commissioning sections of the specifications.

- The commissioning provider compiles and updates the design records as design progresses.
- The Commissioning Authority shall deliver regular commissioning progress reports and comments and recommendations from design reviews to EPA project manager. The Commissioning Authority shall submit updates of the design records, initial construction phase commissioning plan and commissioning specifications.
- The review performed by the Commissioning Authority shall determine that the documents are consistent with the design intent, specify commissionable systems, include inspection and testing details, include equipment parameters that can be verified, incorporate a layout that allows testing and maintenance and fully describe the Commissioning process for the contractors. The Commissioning Authority will also review the contract documents to confirm that each piece of equipment or system is capable of being tested and has objective performance parameters that can be confirmed.

The EPA Project Manager shall monitor the design phase process and shall make certain that procedures are in place within the team so issues the Commissioning Authority raises are reviewed and the team comes to a consensus. If a consensus cannot be reached on an issue, the team should document the issue, and EPA should provide a decision and direction in consultation with the appropriate design professional.

### 1.2.3 **BIDDING/CONTRACT NEGOTIATION PHASE**

The Commissioning Authority will participate in the pre-bid conference presenting a brief overview of the commissioning process and answer specific questions posed by the Contractors. The Commissioning Authority may review bids, alternates, and addendums to ensure that commissioning and the Owner's Project Requirements are not compromised by the changes.

### 1.2.4 **CONSTRUCTION PHASE**

The main construction phase commissioning tasks are listed below:

- The Commissioning Authority will update the construction phase commissioning plan, which includes a list of all systems and specific equipment and components to be commissioned, the process to be followed, communications, reporting and documentation protocols, and an estimated schedule for the commissioning process. The final draft of the Commissioning Plan will be completed during the early stages of construction after all equipment submittals have been approved and before equipment has arrived on the site. The Plan will start with the requirements on a system-by-system basis and on the actual design and the equipment ordered. The Commissioning Plan developed at this point will have detailed information on the support required from contractor and responsible subcontractor personnel.
- The Commissioning Authority will coordinate a construction phase commissioning kickoff meeting that include the EPA project manager, construction manager, design team, Commissioning Authority, and respective representatives from the general contractor and mechanical, electrical, controls, and TAB subcontractors. At this meeting, the Commissioning Authority outlines the roles and responsibilities of each project team member, specifies procedures for documenting commissioning activities and resolving issues, and reviews the preliminary construction phase commissioning plan and schedule.
- The Commissioning Authority will attend periodic planning meetings to update parties involved in commissioning. During the initial stages of construction, the commissioning provider may attend regular construction meetings and hold a line item on the agenda. Later in construction the commissioning provider may coordinate entire meetings devoted to commissioning issues.
- The Commissioning Authority will develop and keep a record of issues and findings throughout the construction phase commissioning process that require further attention, tracking, or correction.
- The Commissioning Authority reviews and comments on contractor submittals of equipment to be commissioned during the normal submittal review process and forward them to the EPA Project Manager and designer.

- The Commissioning Authority should assist the EPA Project Manager in monitoring the development of coordination drawings to ensure interface between trades.
- The Commissioning Authority reviews the O&M manual to ensure that it complies with the specifications, is complete, clear, and is well organized and accessible for use by the O&M staff.
- The Commissioning Authority will visit the construction site periodically, note any conditions that might affect system performance or operation and provide construction observation reports.

#### 1.2.4.1 **FIELD VERIFICATION**

The Field Verification phase of commissioning starts when the Commissioning Plan is completed, equipment is ordered, and construction begins. The Field Verification phase lays the foundation for equipment startup by confirming that installed equipment can function in a safe and effective manner.

The Commissioning Authority will develop and provide construction checklists for installation, start-up and initial checkout of the equipment and systems to the contractor for execution. These checklists will also incorporate manufacturers' requirements. The Commissioning Authority will witness some of the start-up execution and will spot-check selected items on the checklist prior to functional testing. The contractor will execute construction checklists provided by the Commissioning Authority and equipment manufacturer and submit them to the Commissioning Authority for review before functional testing begins.

#### 1.2.4.2 **FUNCTIONAL PERFORMANCE TESTING**

Functional performance testing is conducted to verify that the performance of all integrated systems meets the specified objectives defined in the Design Intent. Functional performance testing ensures that equipment and systems are installed correctly, tested, and adjusted so that they operate efficiently and according to design intent under a variety of conditions. This testing is intended to document the completion and performance of all components, equipment and systems.

Functional performance testing should progress from functional verification to performance verification in sequence, from individual equipment or components through subsystem operation to complete systems. At the end of the testing, every mode of building and system operation, all system equipment, system interfaces, and every item in the control sequence description will be proven operational under all normal operational modes including load, in all seasons, and under abnormal or emergency conditions.

##### a. Functional Verification

Equipment is to be started up for the first time with required factory representatives in attendance. The equipment should be tested at all required speeds and preliminary programming should be completed as required to allow subsequent safe and easy starting.

- The Commissioning Authority will develop written test procedures manage, witness, and document the functional tests, with the actual hands-on execution of the test procedures typically carried out by subcontractors, particularly the controls contractor.
- Acceptable performance is reached when equipment or systems meet specified design parameters under full-load and part-load conditions during all modes of operation, as described in the commissioning test requirements of the specifications and commissioning plan (some testing will be completed by monitoring system operation over time through the building automation system or data loggers a few weeks after occupancy).
- The Commissioning Authority will not re-test systems that have been tested and approved by regulatory authorities. The Commissioning Authority will prepare test plans, assist with execution and document tests of commissioned equipment overseen by regulatory authorities.
- The Commissioning Authority should assist in the programming of the BAS to include the trend logging of a selected group of key performance indicators. These indicators include temperatures and pressures for boiler and chiller operations, duct pressures, outside airflows, and some typical variable air volume terminals operating parameters, and unitary equipment performance parameters.

## Appendix B - Commissioning Guidelines

b. Performance Verification

After equipment has been proved at startup, the Commissioning Authority to confirm that the pieces work together will conduct Functional Performance Tests, which are the heart of the Commissioning process.

- Functional tests will include checking BAS parameters, such as programmed addresses, sensor calibration factors, occupied/unoccupied programming, and trend logging. Programming charts, sequences of operation, block wiring diagrams, and wiring termination diagrams should be included in the report. All BAS tuning variables, such as response times, damping variables, delays, and interlocks, should be included in the report. Laboratory and other critical facilities will have the control input and output points loop calibrated (inputs will be simulated with signal generators).
- The subcontractor's Testing, Adjusting, and Balancing report will be checked for accuracy by sampling the report data. If a substantial failure rate is encountered, all failures should be corrected and a different sample chosen for a repeat test. The EPA project manager may elect to have the Commissioning Authority to perform TAB.
- As Functional Performance Tests proceed, the Commissioning Authority may find a number of items that do not appear to work as intended. The Commissioning Authority will need to perform a varying amount of re-testing because of system and equipment failures during the initial testing. The amount of retesting that is paid for by the EPA and the amount that is passed back to the Contractor should be very clearly spelled out in the construction contract.
- The Commissioning Authority will verify the accuracy of facility record drawings.

**1.2.4.3 FINAL AND POST ACCEPTANCE PHASE**

When the requirements of the contract documents and Commissioning Plan have been completed and satisfactorily documented and any additional required documentation has been completed, submitted to the design professionals, and accepted, the Commissioning Authority should recommend Final Acceptance of the building and all building systems. The recommendation is issued subject to any outstanding issues or deficiencies that cannot be resolved until a future date.

The Post-Acceptance Phase is an important step in ensuring the effective, ongoing functioning of a facility's building systems. As use and function of facilities change, the building systems need to be adapted to the changing requirements of occupancy and utilization. It is appropriate to maintain a history of the facility, recording changes and verifying the effect on the previously commissioned systems.

The Post-Acceptance Phase includes the completion of any outstanding functional performance tests, a post-construction review, at a set or variable period after construction, evaluation and verification that the design intent of the building is still being met and ongoing monitoring.

Post-acceptance commissioning is the continued adjustment, optimization, and modification of the HVAC system to meet specified requirements. It includes updating documentation to reflect minor set point adjustments, system maintenance and calibration, major system modifications, and provision of ongoing training of operations and maintenance personnel. The objective of post-acceptance commissioning is to maintain the performance of the building systems throughout the useful life of the facility in accordance with the current design intent.

A post-construction review should be scheduled a set number of years after completion of construction or in response to significant changes in the facility structure, equipment or in the use of the facility. As-built documents must be revised to reflect modifications made to any part of the facility or the building systems. Any change in usage, installed equipment, loads, or occupancy must be carefully monitored and documented. In addition, any system servicing and maintenance problems should be documented. If the variations are significant enough to warrant a recommissioning of the individual systems, or as a method of continued maintenance, an earlier review should be conducted.

**1.2.4.4 DOCUMENTATION**

The Commissioning Authority develops the following documentation during construction phase:

- Updated construction commissioning plan
- Updated commissioning schedule
- Minutes from commissioning meetings
- Commissioning progress reports
- Reports of submittal reviews
- Updates to the commissioning issues
- Construction checklists and functional test forms
- Report of training completion
- Report of O&M manual review
- Systems Manual
- Commissioning Records.

#### **1.2.5 WARRANTY REVIEW AND SEASONAL TESTING**

The successful completion of commissioning should be a requirement for the issuance of the Final Certificate for Payment. The commissioned building should provide the working environment required for the occupants and the O&M staff can concentrate on establishing an effective Preventive Maintenance Program that should work for the life of the building.

The certain parts of the building mechanical system cannot be adequately tested due to the season of the completion. The commissioning plans should include off-season testing to allow testing certain equipment under the most appropriate test conditions. The systems should also be tested during the spring and fall seasons for partial load performance of mechanical systems.

The commissioning contract should provide the EPA with the ability to engage the Commissioning Authority for occasional, informal consultations throughout the warranty period or during approximately the first year of building operation.

#### **1.2.6. FINAL COMMISSIONING REPORT**

By the completion of training the Commissioning Authority should have completed the Commissioning Final Report. This report should contains copies of the following:

- Design Intent
- Basis of design
- Pre-functional checklists complete
- Functional checklists complete
- TAB reports
- System schematics
- Control strategies and set points
- Deficiency log
- Guidelines for energy accounting.

The Commissioning Final Report, the TAB report, the O&M manuals, and the record drawings and specifications form the documentation that will be left with the O&M staff. Additional information on building controls that includes block-wiring diagrams; as-built control diagrams and sequences of operation will also be included in either the Commissioning Final Report or the O&M manual.

#### **1.2.7. O&M STAFF TRAINING AND DOCUMENTATION**

The Commissioning Authority will have a significant positive impact on O&M training:

- Recommend the necessary O&M staffing (total personnel, qualifications, and required shifts) to satisfy the Owner's operational intent.
- Develop a facility preventive maintenance plan. This task is directly tied to the development of the O&M staffing. The Commissioning Authority shall develop a facility preventive maintenance plan making best use of O&M staffing.
- The Commissioning Authority shall reviews the operation and maintenance manuals and verifies that they are complete and available for training sessions. Prepare framed instructions showing the sequence of operations and interoperability for major systems and component.

Appendix B - Commissioning Guidelines

- The Commissioning Authority ensures that the contractor uses adequate training plans and that the training is completed per the contract documents. The Commissioning Authority should provide training agendas to the contractor's/manufacturer's trainers to review and use.
- The Commissioning Authority shall compile a Systems Manual consisting of the design record; space and use descriptions; single line drawings and schematics for major systems; control drawings; sequences of control; a table of all set points and implications when changing them; time-of-day schedules; instructions for operation of each piece of equipment for emergencies, seasonal adjustment, startup and shutdown; instructions for energy savings operations and descriptions of the energy savings strategies in the facility; recommendations for recommissioning frequency by equipment type; energy tracking recommendations; and recommended, standard trend logs with a brief description of what to look for in them. The Systems Manual with O&M Manuals will form the Master O&M Manual.
- The Commissioning Authority shall prepare a recommended list of spare parts, bench stock, and special tools/equipment required for the first year of building operation.
- The Commissioning Authority shall deliver a final commissioning report, summarizing the commissioning effort with the Commissioning Authority's view on each piece of commissioned equipment relative to installation and start-up, functional performance, O&M documentation, and training. The Commissioning Record also contains the commissioning plan, functional tests, individual commissioning reports, reviews, and issues log.

**1.2.8. COMMISSIONING PROCESS MATRIX**

<b>Task</b>	<b>Description</b>	<b>Documents</b>
Commissioning Authority Selection	Develop an RFP for commissioning services.	RFP Format Scope of Work Scoring Matrix
Commissioning Contract	Negotiate, prepare and execute a commissioning contract.	Commissioning Contract
Design Team Kickoff Meeting	Initial "Kickoff Meeting" with the Design Team to establish the purpose and proposed process for commissioning the facility and to establish the individual roles.	Design Commissioning Plan
Owner Performance Requirements (OPR)	In cooperation with the EPA and the Design Team, the Commissioning Authority prepares a design intent summary document.	Owners Performance Requirements (OPR) Summary
Basis of Design	The design team prepares a Basis of Design document.	Draft Basis of Design
35% Plan Review	Complete thorough reviews of the 35% plan documents and submitted criteria (engineering calculations, system selection and major component selection).	Comments
65% Plan Review	Review 65% Design Documents (zoning requirements, specifications, typical room layouts, system main layouts, riser layouts, standard details, schedules and coordination requirements).	Comments Draft Commissioning Plan, Commissioning Specifications
95% Plan Review	Draft Construction Commissioning Plan, Commissioning Specifications and Supplemental Commissioning Language for other sections. Review 95% Design Documents Updated Commissioning Plan, Final Commissioning Specifications	Commissioning Specifications Draft Construction Commissioning Plan

<b>Task</b>	<b>Description</b>	<b>Documents</b>
Pre-bid Meeting and Assistance During Bidding process.	Pre-bid meeting to assist contractors in answering any questions about the systems or the commissioning process.	Written Responses or Recommendations
Construction Commissioning Kick-off meeting	An initial commissioning meeting with all contractors and commissioning team members to establish the purpose and proposed process for commissioning this facility.	Final Commissioning Plan with specific individual responsibilities identified.
Duration Schedule for Commissioning Activities	Duration schedule for the contractors for the commissioning activities required by the commissioning plan.	Duration Schedule
Submittal & Shop Drawing Review	Review all pertinent approved shop drawings to support the Commissioning Process. Submittals & Shop drawings will be reviewed for commissionability, maintainability and for compliance to the OPR.	Commissioning Review Log
Construction Commissioning Plan	The final commissioning plan will incorporate all changes established by review with EPA and the design team. The final commissioning plan will also include complete FIV, OPT and FPT protocols for each system.	Final Construction Commissioning Plan FIV, OPT and FPT documents and protocols.
Field Inspection Verifications (FIV)	Inspect the progress of construction with respect to the systems being commissioned; verify that the construction complies with the plans & specifications and construction quality practices.	FIV Check Sheets, Daily Log, Commissioning Issues Log
Commissioning Team Meetings	Commissioning meetings on a regular basis with the commissioning team to review progress of the commissioning effort and reinforce individual responsibilities.	Commissioning Issues Log
Complete all FIV's	Complete all field inspection verifications.	FIV check sheets, Commissioning Issues Log
Operational Performance Tests (OPT)	Observe or facilitate all equipment and system start up procedures. The Contractor will execute all start up and point-to-point tests and the Cx will witness execution of all OPT's.	Completed OPT's, Commissioning Issues Log
Functional Performance Tests (FPT)	Observe and facilitate all FPT testing. FPT's shall be designed by the Commissioning Authority and performed by the contractors.	FPT Check Sheets, Commissioning Issues Log
Operator Training	Work with the contractor and owner to schedule and plan training activities so that training occurs in a coordinated and coherent fashion. Contractors and vendors provide all training.	Coordinated Training Agendas
Prepare Final Commissioning Report	Based on the accumulated commissioning work completed as described above, assemble the data into a final commissioning report.	Final Commissioning Report
Deferred (Off season) Testing	Conduct any testing required by the commissioning plan that was deferred from the acceptance period.	Warranty Commissioning Plan, FPT Test check sheets

Task	Description	Documents
Ten-Month Warranty Visit	Inspect the site and interview building operating personnel to identify any outstanding warranty failures and to identify any persistent equipment failure issues that should be handled within the warranty period.	Commissioning Warranty Issues Log, Commissioning report addenda

**1.3 PREVENTIVE OPERATION AND MAINTENANCE PROGRAM**

In order to maintain equipment reliability and optimize facility operation after building turnover, Commissioning Authority should develop a customized preventive operations and maintenance program. The goal of a Preventive Maintenance Plan is to improve equipment reliability and increase equipment life. A functional Operation & Maintenance Plan optimizes facility operation to provide significant energy savings and comfort benefits.

The Commissioning Authority should be a valuable training source not only for the specifics of operating and maintaining the commissioned equipment, but also for providing the background information needed to assist the EPA’s O&M staff in understanding system operations and being able to apply practical preventive maintenance functions.

**1.4. RETRO COMMISSIONING AND CONTINUOUS COMMISSIONING**

Retro commissioning is a systematic, documented process that identifies low-cost O&M improvements in an existing building and brings that building up to the design intentions of its current usage. Retro commissioning identifies and solves comfort and operational problems, explores the full potential of the facility’s energy management system, and ensures that the equipment performs properly after space changes have been made.

The retrocommissioning process is a project-specific effort. Each project’s focus and goals depend on the needs of the EPA, the budget, and the condition of the facility and equipment. Retro commissioning most often focuses on:

- Reducing energy and demand costs
- Bringing equipment to its proper operational state
- Reducing occupant complaints
- Improving indoor environmental quality
- Reducing premature equipment failures
- Improving facility operation and maintenance procedures

Retro commissioning project typically occurs in four distinct phases: Planning, Investigation, Implementation, and Project Hand-off.

The primary tasks for the Planning Phase are developing internal goals and objectives and support for the project, selecting and hiring a retro commissioning service provider, assemble the team that will see the project through to completion and develop the retro-commissioning plan.

The primary goals of the Investigation Phase are to understand current operation and maintenance, to identify issues and potential improvements, and to select the most cost-effective ones for implementation. Tasks during investigation should include:

- Interviewing management and building personnel
- Reviewing current O&M practices and service contracts
- Spot testing equipment and controls and trending or electronic data logging of pressures, temperatures, power, air and water flows, and lighting levels and use
- Gather and review facility documentation
- Begin Assessment and Complete Simple Repairs, begin Master List of Potential Improvements
- Develop Diagnostic Monitoring and Test Plans. The retro-commissioning service provider should direct the functional performance tests and assess and analyze the findings.
- Develop an Initial List of Findings
- Assemble an interim report describing the findings and recommendations.

The Implementation Phase activities include Implementation of the major cost-effective repairs and Improvements and verification of results (re-test and monitor).

In the Project Hand-off Phase the retro commissioning process is completed. The final report should include the following:

- Executive summary
- The retro commissioning plan
- The Master List of Findings with a description of the improvements implemented
- A cost/benefits analysis and the actual improvement costs
- A list of capital improvements recommended for further investigation
- The BAS trending plan and logger diagnostic / monitoring plan and results
- All completed functional tests and results
- Recommended frequency for re commissioning
- Documentation of strategies adopted to optimize systems operation
- Updated (or Created) Building Documentation

The retro commissioning service provider either should provide the training or ensure that the contractor/manufacturer provides adequate training for operating staff and perform deferred testing (seasonal testing).

Continuous commissioning is similar to retro-commissioning and begins by identifying and fixing HVAC and comfort problems in the building. In the continuous commissioning, when the commissioning is complete, the team continues to work together to monitor and analyze building performance data provided by permanently installed metering equipment. This process works to ensure that the savings achieved from the commissioning continue to persist over time.

#### 1.5 COMMISSIONING AND LEED™ BUILDING RATING

Fundamental building systems commissioning is a prerequisite for LEED™ building rating and requires having a contract in place to implement the following fundamental best practice commissioning procedures:

- Engage a commissioning team that does not include individuals directly responsible for project design or construction management.
- Review the design intent and the basis of design documentation.
- Incorporate commissioning requirements into the construction documents.
- Develop and utilize a commissioning plan.
- Verify installation, functional performance, training and operation and maintenance documentation.
- Complete a commissioning report.

Additional System Commissioning has 1 credit point allocated and in addition to the Fundamental Building Commissioning prerequisite implement the following commissioning tasks:

- A Commissioning Authority independent of the design team shall conduct a review of the design prior to the construction documents phase.
- An independent Commissioning Authority shall conduct a review of the construction documents near completion of the construction document development and prior to issuing the contract documents for construction.
- An independent Commissioning Authority shall review the contractor submittals relative to systems being commissioned.
- Provide the owner with a single manual that contains the information required for re-commissioning building systems.
- Have a contract in place to review building operation with O&M staff, including a plan for resolution of outstanding commissioning-related issues within one year after construction completion date.

#### 1.6 DEFINITIONS

Commissioning Authority - An independent party with no affiliation to the design team or participating contractors, who implements the overall commissioning process.

Design Intent - Design Intent defines the benchmark by which the success of a project is judged. It describes EPA's program for the planned facility, explains the rationale behind the ideas, concepts and criteria for the facility. The Design Intent document is updated and increased in detail with each phase of the design. The initial Design Intent document is a detailed explanation of the facilities objectives and its functional and operational needs, occupancy requirements, general quality of materials and construction, intended levels and quality of environmental control, performance criteria, environmental needs and budget considerations and limitations. The Design Intent document is the starting point for the development of the Basis of Design. A

## Appendix B - Commissioning Guidelines

Design Intent document is written by the design team in consultation with the EPA and with an input from the Commissioning Authority.

Basis of Design - The documentation of the primary thought processes and assumptions behind design decisions that are made to meet the Design Intent. It shall respond to, and be consistent with, performance criteria specified in the Design Intent document (Some reiteration of the design intent may be included). The Basis of Design is written by the design team and describes codes, standards, operating conditions, and design conditions, weather data, interior environmental criteria, other pertinent design assumptions, cost goals, and references to applicable codes, standards, regulations and guidelines. The Basis of Design increases in detail as the design progresses. The Commissioning Authority reviews, comments on, and approves the design progress submissions.

The commissioning specifications provide the bidders with a clear description of the extent of the required verification test. They detail what to test, under which conditions to test, acceptance testing criteria and acceptable test methods. The documentation, reporting, and scheduling requirements for verification testing is also to be included. The verification procedures, which are developed, should include all functional performance tests, including the following at a minimum:

- Testing, adjusting, and balancing test performance
- Equipment performance
- Performance of subsystems consisting of combinations of equipment (such as refrigeration cycle, pumps, chillers, cooling towers, and interconnecting piping)
- Performance of the automatic controls in all seasonal modes
- Integrated system performance
- Performance of all life safety devices and systems as they interface with the subsystems
- Architectural and structural system performance
- Electrical system performance
- Plumbing system performance
- Required operation and maintenance training by the contractor, for the owner, his O&M staff and other relevant staff and the facility's O&M documentation requirements.

Commissioning Plan is a document, or group of documents, that defines the commissioning process at the various stages of project development. The plan must create a procedure that will verify and provide documentation that the performance of the building and its individual systems meet the owner's requirements.

Design Phase Commissioning Plan - The commissioning plan developed during the pre-design phase which outlines each team member's role and responsibilities, sets protocols for communication and reviews, specifies procedures for documenting commissioning activities and resolving issues, and sets the schedule for commissioning activities during the design phase of the project. This plan should develop the extent of the commissioning process and communicate it to all project participants

Construction Phase Commissioning Plan - An extension of the commissioning plan developed during the design phase, which outlines the roles and responsibilities of each project team member, specifies procedures for documenting commissioning activities and resolving issues, and sets a schedule for conducting commissioning activities during the construction phase of the project. It is updated as construction progresses.

Construction Checklist - A checklist to ensure that the specified equipment has been provided, properly installed, and initially started and checked out adequately in preparation for full operation and functional testing (e.g., belt tension, fluids topped, labels affixed, gages in place, sensors calibrated, voltage balanced, rotation correct).

Functional Tests - Tests that evaluate the function and operation of equipment and systems using direct observation or monitoring methods. Functional testing is the assessment of the system's ability to perform within the parameters set up in the Basis of Design. Systems are tested under various modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, etc. The systems are run through all the control system's sequences of operation to determine whether they respond as the sequences state. Functional tests are performed after construction checklists are complete.

Performance Metrics - verification that a specific element in the Design Intent has been met. Performance Metrics are identified throughout the design of the project with as many as possible being generated during the

development of the Design Intent. The design team and Commissioning Authority are responsible for Performance Metrics development.

LEED™ - a voluntary, consensus-based, market-driven building rating system, which was created to provide a complete framework for assessing building performance and meeting sustainability goals based on well-founded scientific standards. The LEED™ rating system is organized into five environmental categories. One of them - Energy & Atmosphere – has prerequisites and number of credits allocated to building commissioning.