

Developing a Proper Scope of Work, Request for Proposal & Commissioning Specification

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Synopsis

In order for the commissioning process to have a successful and positive outcome, the roles and responsibilities of the Project Team must be clear from the project's inception. The role that each team member plays in the commissioning process must be defined in order to prevent confusion, additional costs or duplication of services. The information presented in this paper will attempt to assist the Owner, Architect, Engineer, etc. on the proper procedures for developing a clear and concise scope of work (SOW), request for proposal (RFP) and commissioning specification, thus avoiding factors that can lead to future change orders or delays in project completion. Advice will be offered from a Commissioning Provider's point of view on improving this process in order to properly procure commissioning services. Descriptions of historical problems, their causes and solutions, and issues from past experiences will also be discussed.

About the Author

Joseph Lorino, P.E., LEED is known throughout the power generation industry for his experience in power plant operations. During his 20-year career, he has served in a variety of operations, maintenance, management, and development positions related to stationary power plants and chiller plants. His extensive knowledge in this field has been an asset while being involved with the design, construction, start-up, and commissioning of numerous major boiler and chiller plants throughout the New York metropolitan area. Joining Horizon Engineering Associates, LLP (HEA) in 1998 as Senior Partner, Mr. Lorino has been associated with numerous new commissioning and retro-commissioning projects, as well as the development and acceptance of the commissioning process in the northeast area, especially in the academics field.

Mr. Lorino is a graduate of the State University of New York Maritime College, earning a degree in Marine Engineering with a Nuclear Power Design concentration. He has also earned a Master of Business Administration (MBA) from Columbia University with a concentration in Management. Mr. Lorino is a registered Professional Engineer in the states of New York, Michigan, Connecticut and Ohio. He is a certified High Pressure Stationary Engineer and a Refrigeration Engineer for the City of New York, as well as a LEED 2.0 Accredited Professional. Mr. Lorino is currently a member of the United States Green Building Council (USGBC), Building Commissioning Association (BCA), and the Association of Higher Education Facilities Officers (APPA).

Introduction

ASHRAE Guideline 1-1996: “The HVAC Commissioning Process” defines commissioning as follows:

...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.

As Owners venture into the programming phase of a planned project, it is important to realize that the above definition should be constantly echoing in the back of their minds to ensure the success of their endeavor. One major item in ensuring this success is truly contingent upon the Owner properly procuring the services of an independent Commissioning Authority (CA). This process begins with the development of a commissioning scope of work (SOW) and request for proposal (RFP) used to procure these services. Once hired, it is the responsibility of the CA, with the assistance of the Owner and Design Team, to create the commissioning specification. This document is a detailed description of the scope and objective of the commissioning process during all phases of the project. It must specify scope of work and project team member roles, responsibilities and requirements. Once the commissioning specification has been completed, the Owner may now utilize this document as part of the overall project specification

This paper will attempt to assist the project team members (Owner, Architect, Engineer, etc.) in developing the above described documents in a clear and concise manner. An outline will be presented to educate the project team of this process for any future needs.

Developing a Commissioning Scope of Work

Scope of Work

The objective of commissioning is to confirm and document that the construction team fulfills the functional and performance requirements of the Owner, occupants, and operators. To reach this goal, it is necessary for the commissioning process to establish and document the Owner’s criteria for system operation, performance, and maintainability; as well as, to verify and document compliance with these criteria throughout design, construction, start-up, and the initial period of operation. In addition, complete operation and maintenance (O&M) manuals, as well as training on system operation, should be provided to the building operators to ensure the building continues to operate as intended.

The CA should be involved throughout the project from the pre-design through the warranty phase. The primary role of the CA during the overall design phase is to develop detailed commissioning specifications and review design to ensure it meets the owner’s objectives. During construction, the CA develops and coordinates the execution of a testing plan, which includes observing and documenting all system’s performance to ensure that systems are functioning in accordance with the design objectives and the contract documents. The CA is not

responsible for design or general construction scheduling, cost estimating, or construction management, but may assist with problem-solving or addressing non-conformance issues or deficiencies. Generally, this section should include the following commissioning services:

- Documenting the Owner's requirements
- Developing an initial design intent
- Developing a Commissioning Plan
- Assisting the design team in developing a commissioning specification, reviewing design documents, shop drawings and submittals, developing acceptance procedures and training requirements and developing a Systems Manual
- Organizing a commissioning team
- Developing and coordinating a commissioning schedule
- Performing construction inspections
- Supervising acceptance tests
- Organizing O&M personnel training
- Preparing the Systems Manual
- Preparing the Final Commissioning Report
- Organizing the final as-built records
- Providing warranty and seasonal testing assistance

The above services should be detailed in the scope of work in the following commissioning phases:

1. Programming & Schematic Design Phase
2. Design Development Phase
3. Bid Phase
4. Construction Phase
5. Post Acceptance Phase (warranty & seasonal testing)

The following is an example of certain tasks which may be included in the scope of work:

Programming & Schematic Design Phase

1. Aid in the selection of an Architect and Engineer.
2. Assemble commissioning team, hold a scoping meeting and identify responsibilities.
3. Develop a draft commissioning plan.
4. Attend commissioning meetings as needed with project manager and design team.
5. Review the owner objectives documentation (design intent) for clarity and completeness.

Design Development Phase

1. Coordinate the commissioning work during design phase.

2. Perform focused reviews of the design, drawings and specifications at various stages of development (during schematic design, design development and contract document phases).
3. Assist, review and approve the development and updating of the Design Record documentation by design team members (Design Intent, Design Narrative; Design Basis).
4. Develop full commissioning specifications for all commissioned equipment. Coordinate with and integrate into the specifications of the architect and engineers.
5. The commissioning specification will include a detailed description of the responsibilities of all parties, details of the commissioning process; reporting and documentation requirements, including formats; alerts to coordination issues, deficiency resolution; construction checklist and startup requirements; the functional testing process; specific functional test requirements, including testing conditions and acceptance criteria for each piece of equipment being commissioned.
6. Coordinate a commissioning meeting where the engineering design team and the CA discuss integration issues between equipment, systems and controls to ensure that all responsibilities are clearly described in the specifications.

Bid Phase

1. Attend pre-bid meeting to answer commissioning related questions.

Construction Phase

1. Perform the tasks and functions in the specifications ascribed to the commissioning authority as identified in the specifications.
2. Coordinate and direct the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules. The commissioning authority and construction manager shall work in conjunction to coordinate all testing, inspecting and site specific activities pertaining to commissioning. The commissioning authority must also ensure that all commissioning activities are incorporated into the construction schedule.
3. Plan and conduct commissioning meetings as needed and distribute minutes to the commissioning team.
4. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures. Before startup, gather and review the current control sequences and interlocks and work with contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
5. Review normal contractor submittals applicable to systems being commissioned for compliance with commissioning needs and design documents, in conjunction with the A/E reviews.

6. Review requests for information and change orders for impact on commissioning and owner's objectives.
7. Review coordination drawings to ensure that trades are making a reasonable effort to coordinate.
8. Write and distribute commissioning checklists for all applicable equipment prior contractor start-up. These checklists shall include static inspections, pre-functional tests, functional tests and setpoint adjustments
9. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies regarding the commissioning of any system or single piece of equipment.
10. Witness HVAC piping pressure test and flushing, sufficient to be confident that proper procedures were followed. Include testing documentation in the Commissioning Record.
11. Witness any ductwork testing and cleaning sufficient to be confident that proper procedures were followed. Include documentation in the Commissioning Record.
12. Complete commissioning checklist for both the static and pre-functional testing unless specified. Inspect 100% of the equipment unless otherwise specified.
13. Document systems startup by reviewing start-up reports and by selected site observations.
14. Approve air and water systems balancing by spot testing and by reviewing completed reports
15. With necessary assistance from the specifications and submittals, write the functional performance test procedures for equipment and systems. This will include manual functional testing, energy management control system trending and may include stand-alone data-logger monitoring. Submit to CM for review and approval if required.
16. Analyze functional performance trend logs and monitoring data to verify performance.
17. Coordinate, witness and document manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved. The functional testing shall include operating the system and components through each of the written sequences of operation, and other significant modes and sequences, including startup, shutdown, unoccupied mode, manual mode, staging, miscellaneous alarms, power failure, security/fire alarm when impacted and interlocks with other systems or equipment. Sensors and actuators shall be calibrated during construction check listing by the installing contractors, and spot-checked by the commissioning provider during functional testing.

Tests on respective HVAC equipment shall be executed, if possible, during both the heating and cooling season. However, some overwriting of control values to simulate conditions shall be allowed. Functional testing shall be done using conventional manual methods, control system trend logs, and read-outs or stand-alone data loggers, to provide a high level of

confidence in proper system function. This must first be approved by the owner and/or the CA.

18. Maintain a master deficiency log with Internet access and a separate record of functional testing. Report all issues as they occur directly to the CM. Provide directly to the CM written weekly reports and test results with recommended actions and deficiency updates.
19. Review equipment warranties to ensure that the building owner's responsibilities are clearly defined.
20. Oversee, approve and possibly perform the training of the building owner's operating personnel.
21. Review and approve the preparation of the O&M manuals for commissioned equipment.
22. Compile a Commissioning Report, which shall include:
 - A. A brief summary report that includes a list of participants and roles, brief building description, overview of commissioning and testing scope, and a general description of testing and verification methods. For each piece of commissioned equipment, the report should contain the disposition of the CA regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:
 - 1) Equipment meeting the specifications
 - 2) Equipment installation
 - 3) Functional performance and efficiency
 - 4) Equipment documentation
 - 5) Operator training
 - B. All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc., shall also be listed. Each non-compliance issue shall be referenced to the specific functional test, inspection, trend log, etc. where the deficiency is documented.
 - C. Also included in the Commissioning Record shall be the issues log, commissioning plan, progress reports, submittal and O&M manual reviews, training record, test schedules, construction checklists, start-up reports, functional tests, and trend log analysis.
23. Compile an Operations Manual that consists of the following: owner objectives (by owner); design narrative and basis of design (by designer); performance metrics, if completed during design; space and use descriptions, single line drawings and schematics for major systems (by designer); control drawings, sequences of control (by contractor); and a table of all setpoints and implications when changing them, 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 retro-commissioning frequency by equipment type, energy tracking recommendations, and recommended standard trend logs with a brief description of what to look for in them (all by the CA).

Post Acceptance Phase

1. Coordinate and supervise required seasonal or deferred testing and deficiency corrections and provide the final testing documentation for the Commissioning Report and O&M manuals.
2. Return to the site at the 10th month of the 12-month warranty period and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have with operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports and documents and requests for services to remedy outstanding problems.

Systems to be Commissioned

A complete list of systems and associated systems should be included in the scope of work to ensure that the CA is well aware of the project's requirements. This will avoid any future misconceptions especially during the commissioning contract bidding process. Such equipment may include but not be limited to:

- Central building automation system
- All equipment of the heating, ventilating and air conditioning systems
- Scheduled or occupancy sensor lighting controls
- Daylight dimming controls
- Refrigeration systems
- Emergency power generators and automatic transfer switching
- Uninterruptible power supply systems
- Life safety systems (fire alarm, egress pressurization, fire protection)
- Laboratory, clean room, hoods and pressurization
- Electrical
- Domestic & process water systems
- Equipment sound controls and testing
- Data & communication
- Paging systems
- Security systems
- Irrigation
- Plumbing
- Vertical transportation
- Medical gases
- Building envelope
- Process instrumentation controls

As previously noted, the CA should not be responsible for the design concept, design criteria, code compliance, design or general construction scheduling, cost estimating or construction management of the project. The CA may assist with problem solving or resolving non-

conformance or deficiencies but ultimately that responsibility lies with the design team. Once again, the primary role of the CA is to develop and coordinate the execution of a testing plan, observe and document performance of whether the systems are installed and functioning in accordance with the contract documents. This statement should be clearly noted in the scope of work.

Developing a Commissioning Request for Proposal (RFP)

Now that the SOW has been clearly developed, the next step is to take this document and transform it into a Commissioning RFP. This RFP should include the complete SOW as well as the following sections:

- Letter of Introduction
- Project Introduction Section
- Project Background
- Scope of Work
- Assumptions
- Systems to be Commissioned
- Bidder Qualifications
- Instructions to Bidders
- Budget Breakdown

The abovementioned items will be discussed in detail in this paper.

The development of both the commissioning SOW and the RFP is an important first step that Owners should use to initiate commissioning services for the intended project. These documents outline the work to be performed, instructions for preparing and submitting the bid, anticipated project schedule, required qualifications for all bidders, deadline for submission and legal statements. The RFP package should contain everything required to prepare the proposal price and if prepared correctly, leaves little room for uncertainty. It breaks down the job and spells out any limiting factors or circumstances that will hinder the contractor from performing the work under normal conditions and during normal working hours.

The bidder must include an itemized breakdown in tabular form of all costs and time associated with certain tasks. This table prevents the bidder from overcharging the project to make more profit or lowering the cost of the work in order to get the bid. It also enables the Owner the ability to compare the bids on a level field. An optional section may include the request for previous references from other projects. These would usually be similar in project specifics, size, usage, budget, location, etc. to demonstrate to the Owner that the bidder's firm is experienced in this type of project and has the resources to meet the needs of the facility.

Below please find an example of a typical document containing both an RFP and SOW:

RFP Introduction Section

This section should begin by listing the key contact information of the project. This includes:

- Project Name
- Project Address
- Owner
- Owner's Representative
- Contact Information
- Architect
- Engineer
- Project Manager

This key information will be readily available to the bidder should it be required during the bidding process.

Project Background

In this section, the bidder will be initially introduced to the project. The first sentence of this section should state the purpose of the RFP. *“Horizon University (Owner) seeks the services of a qualified commissioning firm for a new biomedical science research building”* may be a possible introductory sentence. Additionally, the following items should be noted in this section:

- Project Gross Square Feet
- Usage (academic, medical, research, residential, etc.)
- Number of Floors
- Construction Classification
- Location
- Project Budget
- Space Usage Percentage

Once this data is described to the bidder, the current status of the project should be stated next. This would include the key milestones that have already been completed such as the programming and schematic design phase or the Basis of Design document. These completed items may be available to the bidder for review and should be noted in this section. Also, the author of the RFP should list key upcoming dates for the bidder as well. These dates may include:

- Commissioning Contract Award
- Completion of Design Development Package
- Phases of Construction Document Release Packages
- Construction Start Date
- Anticipated Occupancy Date

The Project Background section should continue to describe the project's construction delivery method. Some examples of this may include:

- **Traditional Approach:** Owner individually solicits the services of a Design Team, Equipment Manufacturers, Contractors, Commissioning Authority, TAB Specialist, etc.
- **Guaranteed Maximum Price (GMP):** Owner solicits the services of a Design Team, Commissioning Authority and a Construction Manager at Risk with a GMP, based on a percentage of documents, who manages the sub-contractors and TAB Specialist.
- **Design / Build:** Owner solicits the services of a Commissioning Authority and a Design / Build firm to provide all services to complete the project.

If the Owner is pursuing LEED certification, it should also be noted in this section as well. A description of the CA's involvement in the LEED document process should be briefly discussed here as well. Other items may include the project's target goal (certified, silver, gold or platinum) and whether the project is only fulfilling the LEED Energy & Atmosphere Prerequisite 1: Fundamental Building Systems Commissioning or pursuing Credit 3: Additional Commissioning as well.

Finally, the Owner should specify the documents that are available to the commissioning bidder to view. These may include any documents developed in the program phase such as the design intent, schematic designs, programming report, initial specifications, etc. and the place and time available for viewing.

Scope of Work

(It is suggested that the SOW section previously developed should be inserted in this section)

Project Assumptions

The project is usually in either the schematic design phase or in the early stages of the design development phase at the point the CA enters the project, so the Owner must assume that certain items have not been developed and will be delivered in the near future. These items may include an adequately written design intent, basis of design, full sequence of operation for all equipment, O&M manuals delivered on time for the development of commissioning checklists, etc.

Systems to be Commissioned

(It is suggested that the "systems to be commissioned" section previously developed in the Scope of Work should be inserted in this section)

Bidder Qualifications

(The following passage may be utilized in this section)

It is the desire for the person designated as the site CA to satisfy as many of the following requirements as possible:

- Acted as the principal Commissioning Authority for at least three (3) projects over _____sf. with similar usage (academic, medical, research, residential, etc.)
- Extensive experience in the operation and troubleshooting of HVAC systems, energy management control systems.
- Extensive field experience is required. A minimum of five (5) full years in this type of work is required.
- Knowledgeable in building operation, maintenance and training.
- Knowledgeable in testing and balancing of both air and water systems.
- Experienced in energy-efficient equipment design and control strategy optimization.
- Direct experience in monitoring and analyzing system operation using energy management control system trending and stand-alone data logging equipment.
- Excellent verbal and writing communication skills. Highly organized and able to work with both management and trade contractors.
- Experienced in writing commissioning specifications and commissioning plans.
- A bachelor's degree in mechanical or electrical engineering is strongly preferred, and P.E. certification is desired, however, other technical training, past commissioning, and field experience will be considered.
- Membership with the Building Commissioning Association will be considered a plus.

The required expertise for this project will be based on the skill and experience set of the full team making the proposal. A member of the prime firm will be the designated Commissioning Provider who is the member of the team that will coordinate the commissioning activities from the technical perspective. This party may not necessarily be the team's overall project or contract manager. The Commissioning Provider must have significant building commissioning experience, including technical and management expertise on projects of similar scope. If the Commissioning Provider or prime firm does not have sufficient skills to commission a specific system, the prime firm shall subcontract with a qualified party to do so. Subcontractor qualifications shall be included and clearly designated in the response to this RFP.

Instructions to Bidders

(The following passage may be utilized in this section)

Proposals need not be lengthy, but shall provide sufficient information to allow the building owner to evaluate the consultant's approach, experience, staff and availability.

1. Limit their proposal to 15 single-sided pages, including graphics. A letter of introduction, section dividers, detailed resumes and the sample work products of item five below are not included in this limit.
2. The proposal must be signed by an officer of the company in order to commit to the project
3. Fill out the attached *Commissioning Firm Experience* form and the *Commissioning Task Listing* form (Exhibits 1 and 2) for each firm on the team. List no more than four projects in Exhibit 2.
4. Provide an organization chart for managing and executing this contract.
5. List the individual(s) who will be the Commissioning Provider for the design phase and for the construction phase of the contract (they may be different people). Describe his or her relevant qualifications and experience. This information is required in addition to any resumes the proposer submits.
6. Provide resumes for key staff and subconsultants. The resumes shall include specific information about expertise in commissioning tasks, (e.g. design reviews, specification writing, commissioning management, troubleshooting, test writing, test execution, energy management, etc.).
7. Briefly describe relevant experience of the proposer's team in the following areas. List each party's involvement.
 - a) projects similar to this one;
 - b) traditional test and balance project;
 - c) O&M writing and training experience;
 - d) energy-efficient equipment design and control strategy optimization.
8. Describe your proposed approach to managing the project expertly and efficiently, including distribution of tasks, travel, duration of which staff will be on site during what periods of time, etc. Describe what approach you will take to integrate the commissioning into the normal design and construction process in order to minimize potential time delays. Describe what you will do to foster teamwork and cooperation from contractors and design team and what you will do to minimize adversarial relationships. Describe how you intend to determine the appropriate level of commissioning effort for the various systems and equipment.
9. As an attachment, provide the following work products that members of the proposer's team wrote. List the team member who actually wrote the document and the projects on which they were used. Work from the designated CA is preferred.
 - a) commissioning plan that was executed (the process part of the plan);
 - b) commissioning specifications; and
 - c) an actual functional test procedure form that was executed.
10. Provide a fixed lump sum total cost to accomplish the work with the breakdown in the budget table format below. Also provide an hourly rate for each team member for work that may exceed the scope. For each phase, provide the percentage level of effort for each of the primary team members.
11. This project will be set up on a time-and-materials basis. Provide both an *estimated* total fee to accomplish the work and an hourly rate for each team member, along with rates and fees

for all other costs that the building owner could incur from the proposer in this contract (travel, mileage, per diem, communications, etc.). For each phase, provide the percentage level of effort for each of the primary team members.

12. The building owner desires a cost proposal with a budget breakdown for the Pre-Design and Design Phase commissioning tasks. For planning purposes, a cost estimate range for the Construction and Warranty Phase tasks shall also be provided, using the form below.

13. Provide a proposed dollar budget to complete this scope of work in the following format. All task amounts include associated meetings, progress reports and direct costs (travel, etc.).

The respondent must submit three (3) copies of the proposal, each signed by an authorized representative of the firm. Facsimiles will not be accepted. Proposals must be submitted to arrive no later than close of business, **5:00 p.m.** on _____, _____ to:

[State the address, contact person, telephone number, fax number, e-mail address]

Budget Breakdown (Example)

<i>Task</i>	<i>Budget (\$)</i>
Pre-Design and Design	
1 Develop or review owner project intent (per scope)	_____
2 Architect / Engineer selection	_____
3 Design documents reviews of plans, specifications; narratives	_____
4 Commissioning plan, specification development and bid meeting	_____
5 Other	_____
Subtotal	_____
Construction	
1 Commissioning plan and submittal reviews	_____
2 Construction checklists; observation of installation and startup	_____
3 Functional test writing	_____
4 Functional test execution and documentation	_____
5 O&M manual, As-built review and training review	_____
6 Compilation of Commissioning Report	_____
7 Systems Concepts and Operations Manual development	_____
8 Meetings	_____
9 Other	_____
Subtotal	_____
Warranty Period	
Seasonal testing	_____
Near-warranty end review	_____
Subtotal	_____
Total	_____

Developing a Commissioning Specification

As the design development stage progresses in a project, it is the responsibility of the Commissioning Authority (CA), along with the Owner and design team, to create the Commissioning Specification. As in all specification documents, the content is based on the design of the project and covers details of the construction plan, requirements of each system's components, necessary testing of systems after installation, etc. in the necessary level of detail.

More specifically, the Commissioning Specification outlines the basic requirements of the commissioning process, which provides a basis for the Commissioning Plan, and the assignment of responsibilities for each party involved in the project. These details ensure that all expectations of the Construction Phase and Acceptance Phase are clearly understood to eliminate confusion over the roles of each group through out the entire process.

The following document is a template for developing Commissioning Specification, and due to its general nature, the CA may need to alter it to fit the specific requirements of each project.

SECTION 01810 – COMMISSIONING OF MECHANICAL, ELECTRICAL, PLUMBING AND FIRE PROTECTION

PART I – GENERAL

1.1 RELATED DOCUMENTS

A. General

1. Work under this contract shall conform under requirements of Division 1, General Requirements, Conditions of the Contract, and Supplementary Conditions. This specification covers commissioning of the MEP systems which solely serve the ***Insert Building Name Here.***
2. Furnish labor and material to accomplish and complete MEP commissioning as specified herein. Complete interim commissioning of MEP systems during initial season operation and follow-up commissioning of required MEP systems during additional season operation.
3. Failure to comply will result in withholding of payments and/or default of contract.

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

- C. The commissioning team shall be made up of representatives from the user, 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 fittings, Building management and controls, test and balance and electrical. The lead person for each trade who will actually perform or supervise the work is to be designated by the contractor 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.
- D. The Commissioning Authority/Agent, retained by the OWNER shall have responsibility for coordinating and directing each step of the commissioning process.
- E. Neither the Commissioning Agent nor the Commissioning Authority will be responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating or construction management.
- F. MEP system installation, start-up, testing and balancing, preparation of O&M manuals, and operator training are the responsibility of the Division 15 MEP Contractors, with coordination, observation, verification and commissioning the responsibility of the Commissioning Authority/Agent. The commissioning process does not relieve Division 15 or Division 16 contractor from the obligations to complete all portions of work in a satisfactory and fully operational manner. Nor any obligation the trades have for operation and maintenance manuals and training.
- G. Definitions
 1. 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. For this project, the commissioning includes construction, start-up, acceptance and training.
 2. Commissioning Authority: The designated person or company retained by the OWNER who is charge of the commissioning process.
 3. Commissioning Agent: the designated person, company, or agent, retained by Commissioning Authority, who implements the overall commissioning process and carries out the tasks necessary to complete the commissioning process.
 4. Commissioning Plan: A document defining the commissioning process, which is developed by the commissioning Agent.
 5. Commissioning Report: A document recording the results of the commissioning process, including the as-built performance of the MEP system and documents all sign-offs. The report will address the following:

- i. Adequacy of equipment with respect to Contract Documents and Design Intent
 - ii. Equipment installation
 - iii. Functional performance and efficiency
 - iv. Equipment documentation
 - v. O&M review, recommendations and training
6. Commissioning Specifications: the contract document that details the objective, scope and implementation of the construction and acceptance phases of the commissioning process as developed in the Commissioning Plan.
 7. Commissioning Team: those people responsible for working together in carrying out the commissioning process.
 8. Functional Performance Testing (FPT): the process of determining the ability of the Mechanical, Electrical and Plumbing systems to deliver heating, ventilating and air-conditioning services in accordance with the final design intent.
 9. User: The Building OWNER.
 10. Design Engineer of Record: The OWNER'S Architectural, Engineering and Other Consultants who prepared the Construction Documents.
 11. 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.

H. The commissioning is a process and its purpose is:

1. To clearly document the design intent
2. To verify that the systems installation and performance is in accordance with the plans, specifications and design intent.
3. To train the user's operators so that they fully understand the design intent and the operation and maintenance requirements of the equipment.

1.2 SCOPE OF WORK

- A. Commissioning work of Division 15 and 16 shall include, participation from the entire commissioning team but not be limited to:
 1. Documentation of the construction process.

2. Ensuring the basis of design as well as the design intent is carried out.
 3. Reporting on the project schedule to the developer.
 4. Assisting the design professional with RFI issues.
 5. Preparing installation checklists.
 6. Preparing functional checklists.
 7. Testing and start-up of the equipment.
 8. Testing, adjusting and balancing of hydronic and air systems.
 9. Cooperation with the Commissioning Agent.
 10. Providing qualified personnel for participation in commissioning tests, including seasonal testing required after the initial testing.
 11. Providing equipment, materials, and labor as necessary to correct construction and/or equipment deficiencies found during the commissioning process.
 12. Providing operation and maintenance manuals and as-built drawings to the Commissioning Agent for verification.
 13. Providing on site and off site 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. Heating and cooling systems
 2. Air handling/air distribution systems
 3. Hydronics distribution systems
 4. Ventilation and exhaust systems
 5. Automatic temperature controls integrated with the MEP Systems
 6. Coordination and functionality with the Building Management Controls System (Division 17000)

7. Domestic Hot Water Heaters and distribution.
 8. Electrical Panels
 9. Lighting
 10. Fire Alarm and Controls
- C. Timely and accurate documentation is essential for the commissioning process to be effective. Documentation required as part of the commissioning process shall be provided to the commissioning agent by the construction manager 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. Operational 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 evaluated and witnessed by the Commissioning Agent. After each grade of checklist and test are complete the system will be upgraded to the next test. Once all systems have completed each check they will be ready to be turned over. The following testing is required as part of the commissioning process:
1. Installation Checklists are comprised of a full range of checks developed that all systems were actually installed correctly. This includes piping is complete, all electric is tied in and complete and all accessories are installed.
 2. Pre-functional checklists 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.
 3. Functional Performance Tests (FPT) shall determine if the MEP 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 MEP Contractor, and where appropriate by other sub-contractors and vendors prior to turnover of building to the User. The training shall include on-site classroom instruction, along with hands-on instruction on the installed equipment and systems.

1.3 QUALITY ASSURANCE

- A. The following reference is a guideline to the commissioning process and should be applied as appropriate.
- B. Reference:
 - 1. ASHRAE Guideline 1-1996: The MEP Commissioning Process
 - 2. ASHRAE Application Handbook – 1995: Chapter 39 – Building Commissioning.
 - 3. ASHRAE Guideline 4-1993: Preparation of Operating and Maintenance Documentation for Building Systems.

I. ROLES AND RESPONSIBILITIES

A. User

- 1. User will advise Commissioning Authority/Agent regarding changes in building occupancy and/or usage.
- 2. User will witness and attend any and all commissioning meetings and testing.
- 3. Assign maintenance personnel and schedule them to participate in meetings and training sessions as follows:
 - a. Construction Phase coordination meeting.
 - b. Initial user 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. Users training session.
- g. Final review at acceptance meeting.
- h. Provide qualified personnel for on-site classroom training

B. Commissioning Authority

1. Review and approve the Basis of Design, Design Intent and Sequence of operations. The CA shall review and approve the contractor submittals and verify the system installation. The CA will also witness sufficient amount of functional tests and review the Commissioning Agent's documentation for completeness. The Commissioning Authority will also assemble written verification that training was conducted in a satisfactory manner.
2. Provide the OWNER with a Commissioning Report that will address the adequacy of the installed systems and equipment with respect to Contract Documents and the Design Intent. In addition, any outstanding commissioning and warranty issues will be identified in the report.

C. Commissioning Agent

1. Develop the commissioning requirements and all related testing verification and quality control sections.
2. Review the shop drawings and submittals to ensure the system are being installed with the design intent and basis of design. In addition review of the shop drawings will also include assisting in coordination and the proper installation of equipment to support operation and maintenance in the future.
3. Prepare the commissioning program required as part of the commissioning specification. Include lists of all contractors for commissioning events by name, firm and trade specialty.
4. Develop detailed pre-test and final test report forms, specifically developed, for each system and piece of equipment installed on the project.

5. Develop and perform the air quality and air pressurization testing as required in the contract documents.
6. Oversee the development and compiling of both the O&M document and Systems an Energy Management Manual.
7. Be available for one year after significant acceptance to monitor warranty period.
8. Develop and begin the continuous commissioning program

D. 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. Provide data on structure, building materials, interior finishes, and furnishings for their effect on indoor air quality.

E. Mechanical Design Professional

1. Provide Construction Documents.
2. The Design Professional retains responsibility for the system evaluation, adequacy of the system to meet design intent, capacity of the system, quality check or any of the other elements of the system design.
3. Participate in inspection at the final construction stage.
4. Review verification and functional performance testing procedures submitted by the Commissioning Authority/Agent, for conformance with Lease Construction Documents.
5. Review testing and balancing report and verification data sheets for system conformance to contract documents. Issue a report noting deficiencies requiring correction to the Commissioning Authority/Agent.
6. Review functional performance testing report for deficiencies in meeting the finalized design intent.

7. Review as-built records as required by contract documents and turn them over to the Commissioning Agent for inclusion in final project documentation.
8. Review and comment on the final commissioning report.
9. Conduct periodic inspections of work in progress to ensure that all systems and equipment are installed according to specifications.

F. Electrical Design Professional

1. Provide documentation or design narratives for electrical services to be for specific MEP equipment requirements.
2. Provide electrical system information confirming compatibility with electrical service requirements specified by the mechanical design professional for all MEP equipment and systems. Provide information necessary for the basis of design.
3. Prepare contract documents that coordinate interfaces between life safety systems MEP and BMCS systems including commissioning specifications.
4. Attend construction – phase coordination meeting scheduled by the commissioning Agent.
5. Participate in the start-up of MEP equipment and systems.
6. Participate in the MEP training sessions as required.
7. Participate in review of shop drawings for MEP equipment.
8. Prepare electrical ladder wiring diagrams indicating power source connections to MEP equipment and systems and interrelationships between life safety systems and MEP 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.

G. Construction Manager

1. Include cost for commissioning requirements of construction manager in the contract price.
2. Construction Manager shall coordinate construction progress with the commissioning schedule to assure that the building envelope and systems that affect operation of the systems being tested are complete prior to testing.
3. Include commissioning requirements in the mechanical, electrical and Building Management System as well as all other sub-contractors, to ensure cooperation of all parties in the commissioning program.
4. Ensure acceptable representation, with the means and Authority to prepare and coordinate execution of the commissioning program as described in the contract documents.
5. Ensure acceptable representation at all commissioning meetings for this project.
6. Issue a statement that testing and balancing work has been completed, and submit the final testing and balancing reports for review.
7. Issue a statement that control systems have been calibrated.
8. Respond to deficiencies identified in verification tests within seven (7) days of notification. The Commissioning Agent can issue an extension upon written notification and approval.
9. Evaluate any performance deficiencies identified in the Functional Performance Testing report for non-performance with contract documents.
10. The equipment supplier shall document the performance of his equipment. The Commissioning Agent shall witness performance testing.

H. HVAC, Electrical, Plumbing, Fire Protection and Contractors

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

2. Include requirements for submittal data, operation and maintenance 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 testing and balancing.
4. Ensure participation of major equipment manufacturers in appropriate training and testing activities.
5. Attend Construction Phase coordination meeting scheduled by the Commissioning Agent.
6. Ensure proper representation at all commissioning meetings.
7. Assist the Commissioning Agent in all verification and functional performances by completing all checklists by the installing trade for approval by the Commissioning Agent
8. Prepare preliminary schedule for Mechanical, Electrical Plumbing system orientations and inspections, operation and maintenance manual submissions, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, testing and balancing and task completion for user by Commissioning Agent.
9. Update schedule as required throughout the construction period.
10. Attend initial training session.
11. Conduct MEP system orientation and inspection at the equipment placement completion stage.
12. Update drawings to the record condition to date and review with the Commissioning Agent for approval no more than 45 days after all material is installed and in place.
13. Gather operation and maintenance data on all equipment, and assemble in binders as required by the Commissioning Specification. Submit to Commissioning Agent 45 days after full submittal acceptance.
14. Coordinate with the Commissioning Agent to provide 48-hour advance notice so that the witnessing of equipment and system start-up and testing can begin.

15. Notify the Commissioning Agent a minimum of two weeks in advance of the time for start of the testing and balancing work. Attend the initial testing and balancing meeting for review of the official testing and balancing procedures.
16. Participate in, and schedule vendors and Contractors to participate in the training sessions as set up by the Commissioning Agent.
17. Provide written notification to the General Contractor and Commissioning Agent that the following work has been completed in accordance with the contract documents, and that the equipment, systems, and sub-system are operating as required.
 - a. MEP equipment including all fans, air handling units, ductwork, dampers, terminals, and all other equipment furnished under this Division.
 - b. Heating and refrigeration equipment, pumping systems, heat exchange 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.
 - 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 operations of the smoke control systems.
 - g. Those building control systems are functioning to control MEP equipment and smoke control systems.
18. The equipment supplier shall document the performance of his equipment. The Commissioning Agent shall witness performance testing.
19. Provide a complete set of as-built records to the Commissioning Agent.

I. 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 Agent.
3. Submit the testing and balancing procedures and testing and balancing plan to the Commissioning Agent and Design Professional for review and acceptance.
4. Attend the testing and balancing review meeting scheduled by the Commissioning Authority/Agent. Be prepared to discuss the procedures that shall be followed in testing, adjusting, and balancing the MEP system.
5. At the completion of the testing and balancing work, and the submittal of the final testing and balancing report, notify the MEP contractor and the General Contractor.
6. Participate in training sessions as scheduled by the Commissioning Agent.
7. At the completion of testing and balancing work, and the submittal of the final testing and balancing report, notify the MEP Contractor and the General Contractor.
8. Participate in verification of the testing and balancing report, which will consist of repeating any selected measurement contained in the testing and balancing where required by the Commissioning Agent for verification or diagnostic purposes.
9. The equipment supplier shall document the performance of his equipment. The Commissioning Authority/Agent shall witness performance testing.

1.4 DOCUMENTATION

- A. The Commissioning Authority/Agent 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. Approved final test and balance report for the building being commissioned.
 2. All accepted shop drawings of systems equipment. Shop drawings shall be full size sheets folded as required to fit in binders.
 3. All pre-functional performance test checklists, signed by indicating personnel, organized by system and sub-system.

4. All verification and functional performance test checklists/results, signed by indicated personnel, organized by system and sub-system. This information may be used for calibrating the original energy simulation model. The revised model will be used to create the baseline for energy use in the building.
5. Three copies of the operation and maintenance (O&M) manuals specified in the Construction Documents shall be included with the commissioning documentation. The manuals shall be incorporated in the commissioning documentation prior to commencement of Operation & Maintenance training required in this and other sections of the specification. Preparation of Operation & Maintenance manuals shall be as specified in the Contract Documents.

PART 2 – PRODUCTS

2.1 TEST EQUIPMENT

- A. The appropriate Contractor(s) shall furnish all special tools and equipment required during the commissioning process as defined by the Lease Construction Documents. The User shall furnish necessary utilities for the commissioning process.

2.2 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 User upon completion of the commissioning process.

PART 3 – EXECUTION

3.1 GENERAL

- A. A pre-construction meeting of all commissioning team members shall be held at a time and place designated by the User. 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. During the construction process commissioning meetings will take place that will include attendance for all necessary trades or a company representative that are involve in the commissioning process. During the beginning of construction they will take place monthly and increase in frequency as the project progresses.
- C. 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 Construction Documents and related directives, clarifications, and change orders.
- D. The Commissioning Agent shall develop a Commissioning Plan. The Contractor shall assist the Commissioning Agent 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 Agent shall notify the User. The Commissioning Plan can be modified based on the construction schedule and can be done so after consultation with the OWNER at the discretion of the Commissioning Authority.
- E. Acceptance procedures are normally intended to begin prior to completion of a system and/or sub-systems, and shall be coordinated with the Division 14, 15, 16 and 17 contractors. Start of acceptance procedures before system completion does not relieve the contractor from completing those systems as per the schedule.
- F. The Commissioning Agent shall develop a detailed schedule for acceptance procedures and training. The Commissioning Agent shall work in a cooperative manner with the Contractor to assure that the commissioning process does not interfere with the completion of work in accordance with the overall construction schedule.

3.2 PARTICIPATION IN ACCEPTANCE PROCEDURES

- A. The Contractor shall provide skilled technicians to start-up and debug all systems. The Contractor shall also assist the Commissioning Agent in the completion of the installation and pre-functional checklists. Work schedules, time required for testing, etc. shall be requested by the Commissioning Agent 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 Agent 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. Qualifications of technicians shall include expert knowledge relative to the specific equipment involved and a willingness to work with the Commissioning Agent. Contractor shall provide adequate documentation and tools to start-up and test the equipment, system, and/or sub-system.

3.3 DEFICIENCY RESOLUTION

- A. In some systems, improper adjustments, misapplied equipment, and/or deficient performance under varying loads may result in additional work being required to commission the systems. This work shall be completed under the direction of the User, with input from the contractor, engineer, equipment supplier, and Commissioning Agent. Whereas all members shall have input and the opportunity to discuss, debate, and work out problems, the Design Professional 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. If construction operation does not permit accurate demonstration of the testing procedure then seasonal testing or other methods of testing can be implemented. The commissioning Authority will approve all tests. Experimentation to demonstrate system performance may be permitted. If the Commissioning Agent deems the experimentation work to be ineffective or untimely as it relates to the commissioning process, the Commissioning Agent shall notify the User, 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 User 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.
- C. Deficiencies shall be assigned by trade by both the Construction Manager and the Commissioning Agent.
- D. The Commissioning Agent will have jurisdiction of all matters that pertain to the commissioning process and will report directly to the OWNER on all matters including dispute resolution.

3.4 ADDITIONAL COMMISSIONING

- A. Additional commissioning activities may be required after system adjustments, replacements, etc., are completed. The contractor(s), suppliers and Commissioning Agent shall complete this work as part of their contractual obligations. Seasonal

commissioning will be scheduled for pieces of equipment that only operate during specific seasons.

3.5 SEASONAL COMMISSIONING

- A. Seasonal commissioning pertains to testing under full load conditions during peak cooling seasons, as well as part load conditions in the spring and fall. Simulations of peak load conditions shall be implemented wherever possible to allow for complete commissioning of the work.
- B. All seasonal commissioning will be performed by the OWNER's staff with the guidance and supervision of the commissioning agent. The contractors will not be responsible for testing but will be responsible for any deficiencies that discovered from the seasonal testing.

3.6 ACCEPTANCE PROCEDURES

A. Verification Tests

1. Scope of verification tests

Only after the satisfactory completion of the installation checklist, pre-functional checklist and functional performance checklist will the system be ready for acceptance. At no time will acceptance be made for pieces of equipment. Final acceptance will only be for systems that will operate as intended in the basis of design and the design intent.

- 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 conditions and verifications 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
- a. The Commissioning Agent shall be responsible for preparing the scope of these tests. The Commissioning Agent 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.

- b. MEP 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.
 - c. BMCS contractor – provide the services of a controls technician 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.
 - d. Electrical contractor – provide a foreman electrician or office personnel 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 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 Agent shall furnish all measurement instrumentation for the verification tests. All instruments shall have calibrated within the six-month period prior to these tests.

5. Verification Procedures

- a. The Commissioning Agent 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, alarm conditions and combustion if so required.
 2. The Commissioning Agent 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 MEP system being tested performance under normal and full operating conditions.
 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 MEP 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 be included.
 7. Verification of the proper responses of monitoring and control system controllers and sensors shall be included:
- b. The Commissioning Agent shall direct and witness the field verification of the final TAB report.
 1. The Commissioning Agent shall select, at random, 10 percent of the report data for verifications.
 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 rejections of the final TAB report.
5. If there are deficiencies identified during verification, the owner and the construction manager must be notified, and action taken to remedy the deficiency. The Design Professional and the Commissioning Agent, to determine if verification is complete, and the operating system is functioning in accordance with the contract documents, shall review the final tabulated checklist data sheets.

B. Functional Performance Testing

1. Scope of Functional Performance Testing

- a. Functional performance tests shall determine if the MEP 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 Mechanical 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 Agent 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 Agent may need to provide data acquisition equipment to record data for the complete range of testing. This data should be made available for the calibration of the energy simulation model.

5. Functional Performance Test Procedures

- a. The Commissioning Agent shall supervise and direct all functional performance tests.
- b. For each test, the Commissioning Agent 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. Measurement 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 MEP system at the time of testing shall be submitted to the Commissioning Agent.
- b. A preliminary functional performance test report shall be prepared by the Commissioning Agent 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 contractual obligations. The responsible contractor (s) and the specific functional performance test repeated shall correct construction deficiencies.

- c. If it is determined that the MEP system is constructed in accordance with the contract documents, and the performance deficiencies are not part of the contract documents, the User must decide whether any required modifications needed to bring the performance of the MEP 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 User shall determine if a portion or all required functional performance tests should be repeated, and a revised report submitted.

3.7 OPERATING AND MAINTENANCE MANUAL

- A. The operating and maintenance manual shall consist of a sturdy 3-Ring binder with 8-1/2" X 11" sheets in accordance with the Contract Documents as stated in both Division 1 and division 15.

3.8 OPERATING AND MAINTENANCE TRAINING

- A. The MEP Contractor, and appropriate sub-contractors, shall provide comprehensive operating and maintenance instruction on building systems in accordance with the Contract Documents prior to delivery. The instruction shall include classroom instruction delivered by competent instructors based upon the contents of the operating manual.
- B. Each on-site classroom-training period shall be followed by an inspection, explanation and demonstration of the system concerned by the instructors. All specified equipment should be started up and shut down, with the exception of sprinkler system.
- C. The contractor shall be responsible for organizing, arranging, and delivering material on a schedule agreeable to the User.
- D. The contractor shall provide, at or before substantial completion, a proposed agenda and schedule of the above training for approval by the Commissioning Agent and the User.

END OF SECTION

REFERENCES

Sherman, Max C. ASHRAE Guideline 1-1996. Atlanta, GA: ASHRAE, 1996.

John A. Heinz & Rick Casault. The Building Commissioning Handbook, Second Edition.