

## APPENDIX

### COMMISSIONING PROCESS

#### PART 1 - GENERAL

##### 1.01 DESCRIPTION

- A. This Document describes the overall commissioning process and is provided for information only. Commissioning requires the participation of all members of a Commissioning Team as described in this Document. The goal of Commissioning is to ensure that all systems are operating in a manner consistent with the Contract Documents. Each contractor designated as responsible for a commissioned system shall be familiar with all parts of this Document and the responsibilities that are required of each contractor as relates to all other Commissioning Team members. Each contractor shall be responsible for following a Commissioning Plan to be issued by the Commissioning Agent and shall execute all Commissioning responsibilities assigned to them in this and all other related Contract Documents.

##### 1.02 COMMISSION TEAM AND COMMISSIONING TERM DESCRIPTIONS

- A. Architect / Engineer (A/E): The prime consultant (architect) and sub-consultants who comprise the design team, generally the HVAC mechanical designer/engineer and the electrical designer/engineer.
- B. Commissioning authority (CA): An independent agent. The CA directs and coordinates the commissioning activities. The CA does not take an oversight role. The CA is part of the Director's team.
- C. Commissioning Plan (Cx Plan): An overall plan that provides the structure, schedule and coordination planning for the commissioning process.
- D. Commissioning Team (Cx Team): The members of the commissioning team consist of the Commissioning Authority, the Director's Representative, the Commissioning Team Contractors, Subcontractor's, equipment Vendors and the Architect and design Engineers. The owner and the building or plant operator/engineer also may be members of the commissioning team.
- E. Commissioning Team Contractor: (Cx Team Contractor) Contractors responsible for providing the systems specified for Commissioning in Section 019113 – General Commissioning Requirements, of their respective contracts. The Cx Team Contractors are totally responsible for their various Subcontractors and Vendors. Note that each system may have multiple Cx Team Contractors; i.e. - HVAC contractor installs a variable speed drive, and Electrical contractor provides power wiring to the drive.
- F. Director's Representative (DR): The OGS Project Manager or Engineer in Charge of the Construction project, hired and acting on behalf of the Owner.

- G. HVAC Contractor (HC): Cx Contractor responsible for all Commissioning activities associated with the HVAC contract, and all those of HVAC subcontractors and HVAC equipment vendors for Commissioned equipment supplied under the HVAC contract.
  - 1. Typical HVAC Subcontractors.
    - a. Testing and Air Balancing Contractor (TAB).
    - b. Controls Contractor (CC).
- H. Electrical Contractor (EC): Cx Contractor responsible for all Commissioning activities associated with the Electrical contract, and all those of Electrical subcontractors and Electrical equipment vendors for Commissioned equipment supplied under the Electrical contract.
- I. Owner: Client or facility representatives.
- J. Subcontractors (Subs): The subcontractors to the Cx Contractors who provide and install building components and systems.
- K. Vendor: Supplier of equipment.
- L. Functional Performance Test (FT): Test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Functional testing is the dynamic testing of systems (rather than just components) under full operation. 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 CA develops the functional test procedures in sequential written form. The CA coordinates, oversees and documents the actual testing. The Contractor performs the functional tests. FTs are performed after prefunctional checklists and startup are complete.
- M. Prefunctional Checklist (PC): A list of items to inspect and component tests to conduct to verify proper installation of equipment.
- N. Deferred Testing: Functional test procedures approved by the CA and DR to be performed after Functional Completion and post Substantial Completion of the project. Deferred testing may be required due to occupancy requirements, seasonal requirements for testing or deficiencies approved for correction at a later date by the DR.
- O. Functional Completion: Final written approval by the DR that all Commissioning work is complete.

### 1.03 SUMMARY

- A Commissioning: Commissioning is a systematic process of ensuring that (selected) building systems perform interactively according to the design intent and the Owner's operational needs. Commissioning during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:
  - 1. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing contractors.
  - 2. Verify and document proper performance of (selected) equipment and systems.
  - 3. Verify that O&M documentation left on site is complete.

4. Verify that the Owner's operating personnel are adequately trained.
- B. The commissioning process does not take away from or reduce the responsibility of the installing contractors to provide a finished and fully functioning product.

#### 1.04 COMMISSIONING PROCESS

- A. Management:
1. The CA is hired by, and works for, the Director's Representative and/or Owner. The CA directs and coordinates the commissioning activities. All Commissioning Team members work together to fulfill their contracted responsibilities and to meet the objectives of the Contract Documents.
  2. It is noted that the services for the A/E and Commissioning Authority are not provided for in this contract. That is, the Cx Team contractors are not responsible for providing the CA's or A/E's services. Their responsibilities and tasks are listed in this Document to clarify the commissioning process.
- B. Commissioning Process: The following narrative provides a brief overview of the typical commissioning tasks during construction and the general order in which they occur.
1. Commissioning begins prior to construction with a scoping meeting planned, scheduled and conducted by the CA where the commissioning process is reviewed with the commissioning team members. The CA will provide the initial schedule of primary commissioning events at the commissioning scoping meeting. Meeting minutes will be distributed to all parties by the CA.
  2. The CA will develop a commissioning plan to provide guidance in the execution of the commissioning process. A draft copy of the plan will be presented at the scoping meeting for discussion.
  3. The CA will work with the Cx Team contractors according to established protocols to list and schedule the commissioning activities, using his initial listing of events from the draft Cx Plan as a basis. The HC will integrate all commissioning activities into the Construction Progress or Master Schedule.
  4. Additional meetings will be required throughout construction, scheduled by the CA with necessary Commissioning Team members attending, to plan, scope, coordinate, schedule future activities and resolve deficiencies. These meetings will be held monthly or bi-weekly during initial construction and can increase in frequency to as often as one per week in the final months or critical periods of each phase of construction.
  5. After the initial commissioning scoping meeting the CA will update the plan which is then considered the "final" plan, though it may be revised as the project progresses. The Contract Specifications will take precedence over the Commissioning Plan.
  6. Equipment documentation, including O&M manuals are submitted to the CA during the submittal process, including detailed start-up procedures. The CA reviews the O&M documentation for completeness.
  7. The CA works with the Cx Team contractors and their subcontractors to develop startup plans and startup documentation formats for commissioned equipment and systems. This includes providing prefunctional checklists to be completed, during the startup process.
  8. The CA develops specific equipment and system functional performance test procedures. The Cx Team contractors and Subs review the procedures and submit suggestions or comments. Procedures are finalized by the CA.

9. The Cx Team contractors and their subcontractors, under their own direction, execute and document the prefunctional checklists and perform startup and initial checkout for all commissioned systems. The CA documents that the checklists and startup were completed according to the approved plans and will spot check selected equipment prior to performing functional testing.
10. The procedures for Functional Testing are executed by the Cx Team contractors and subcontractors, under the direction of, and documented by the CA.
11. In general, the checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels with prefunctional checklists being completed before functional testing.
12. Items of non-compliance in material, installation or setup are corrected at the Cx Team contractors' expense and the system is retested.
13. Commissioning (Functional Completion) is completed before Project Substantial Completion.
14. The CA reviews, pre-approves and coordinates the training provided by the Cx Team contractors and their subcontractors and verifies that it is completed.
15. Deferred testing is conducted, as specified or required.

#### **1.05 COMMISSIONING RESPONSIBILITIES**

- A. All Commissioning Team Members:
  1. Follow the Commissioning Plan.
  2. Attend commissioning scoping meeting and additional meetings, as necessary.
- B. Architect/Engineer (A/E):
  1. Pre-Construction and Construction Phase:
    - a. Attend the commissioning scoping meeting and selected commissioning team meetings as needed.
    - b. Provide Design Intent and Basis of Design documents.
    - c. Provide any design narrative documentation requested by the CA.
    - d. Perform normal submittal review, construction observation as contracted.
    - e. Any on-site observations required by contract should be completed just prior to system startup.
    - f. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
    - g. Prepare and submit final as-built design intent documentation for inclusion in the O&M manuals.
- C. Commissioning Authority (CA):
  1. The CA is not responsible for design concept, design criteria, compliance with codes, design or construction scheduling, cost estimating, or construction management. The CA may assist with problem-solving, non-conformance or deficiencies, but ultimately that responsibility resides with the Director's Representative, the Cx Team contractors and the A/E. The primary role of the CA is to develop and coordinate the execution of a testing plan and to observe and document that systems are functioning in accordance with the documented design intent, in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CA.

2. Pre-Construction and Construction Phase
  - a. Coordinates and directs 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, schedules and technical expertise.
  - b. Coordinate the commissioning work and, with the DR and Cx Team contractors, ensure that all commissioning activities are scheduled into the Construction Progress Schedule.
  - c. Plan and conduct a commissioning scoping meeting and other commissioning meetings.
  - d. Revise, as necessary, the Commissioning Plan.
  - e. Request and review information (including O&M materials) required to perform commissioning tasks and develop system start-up and checkout procedures.
  - f. Review and approve normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
  - g. Develop an enhanced start-up and initial systems checkout plan with Cx Team contractors.
  - h. Write and distribute prefunctional tests and checklists.
  - i. With necessary assistance and review from installing contractors, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone data logger monitoring or manual functional testing. Submit to Cx Team contractors for review.
  - j. 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.
  - k. Witness all or part of any test, flushing or start-up procedures, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify Director's Representative of any deficiencies in results or procedures.
  - l. Approve prefunctional tests and checklist completion by reviewing prefunctional checklist reports and by selected site observation and spot checking.
  - m. Approve system startup by reviewing start-up reports and by selected site observations.
  - n. Review TAB execution plan.
  - o. Oversee and approve functional testing of Commissioned systems.
  - p. Coordinate, witness, and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
  - q. Analyze any functional performance trend logs and monitoring data to verify system performance.
  - r. Approve air and water systems balancing by spot testing, by reviewing completed reports or by selected site observation.

- s. Maintain a master deficiency and resolution log and a separate testing record. Provide the Director's Representative with written progress reports and test results with recommended actions.
  - t. Review and approve the preparation of the O&M manuals.
  - u. Review equipment warranties to ensure that the Director's responsibilities are clearly defined.
  - v. Oversee and approve the training of the Owners operating personnel.
  - w. Compile and maintain a commissioning record and building systems book(s).
  - x. Provide a final commissioning report (as described in this Document).
3. Warranty Period:
- a. Coordinate and supervise required seasonal or deferred testing.
  - b. Return to the site at 10 months into 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 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, documents and requests for services to remedy outstanding problems.

D. Director's Representative:

- 1. Pre-Construction and Construction Phase:
  - a. Manage the contract of the A/E and of the Cx Team contractors.
  - b. Attend a commissioning scoping meeting and other commissioning team meetings.
  - c. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the Commissioning Plan.
  - d. Facilitate the coordination of the commissioning work by the CA and Cx Team contractors; ensure that commissioning activities are being scheduled into the Construction Progress schedule.
  - e. Review and approve the final Commissioning Plan.
  - f. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CA.
  - g. Observe and witness prefunctional checklists, startup and functional testing of selected equipment.
  - h. Review commissioning progress and deficiency reports.
  - i. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.
  - j. Assist in coordinating the training of Owner's personnel.
  - k. Provide final approval for the completion of the commissioning work.
- 2. Warranty Period:
  - a. Assist the CA as necessary in the seasonal or deferred testing.

- E. Commissioning Team Contractors (Includes Subcontractors and Vendors):
1. Pre-Construction and Construction Phase
    - a. Designate in writing a company representative to act as “coordinator” for all commissioning activities. (Coordinator can be project supervisor or manager).
    - b. Facilitate the coordination of the commissioning work by the CA, and with the CA ensure that commissioning activities are being scheduled into the Construction Progress Schedule.
    - c. Include the cost of commissioning responsibilities in the total contract price. Provide requested documentation, prior to or during the submittal period (prior to normal O&M manual submittals), to the CA for development of start-up and functional testing procedures.
      - 1) Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, installation, start-up and checkout materials that are shipped inside the equipment and field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.
      - 2) The Commissioning Agent may request further documentation necessary for the commissioning process.
    - d. In each purchase order or subcontract written, include appropriate requirements for submittal data, O&M data, commissioning tasks and training.
    - e. Ensure that all subcontractors execute their commissioning responsibilities according to the Contract Documents and schedule.
    - f. Provide a copy of the O&M manuals and submittals of commissioned equipment, through the DR, to the CA for review and approval.
    - g. Provide assistance to the CA in preparing the specific functional performance test procedures. The Cx Team contractors shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests. Assist in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
    - h. Develop a full start-up and testing plan using manufacturer’s start-up procedures and the prefunctional checklists from the CA for all commissioned equipment. Submit to CA for review and approval prior to startup.
    - i. During the startup and initial checkout process, execute all portions of the prefunctional checklists for all commissioned equipment.
    - j. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA.
    - k. Address current punch list items before functional testing. Air and water TAB shall be completed with deficiencies and problems remedied before functional testing of the respective air- or water-related systems.
    - l. Provide skilled technicians to execute starting of equipment and to execute the functional performance tests under the direction of the CA. Ensure that they are available and present during the agreed upon

- schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving. Assist the CA in interpreting the monitoring data, as necessary.
- m. Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, Director's Representative and A/E and retest the equipment.
  - n. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
  - o. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of all warranties.
  - p. During construction, maintain as-built red-line drawings for all drawings and provide final CAD as-builts for contractor-generated coordination drawings. Update after completion of commissioning (excluding deferred testing).
  - q. Provide training of the Owners operating staff using expert qualified personnel, as specified.
2. Warranty Period
- a. Execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
  - b. Ensure that Cx Team contractors correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.
- F. Vendors:
- 1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities for the Owner to keep warranties in force.
  - 2. Provide information requested by CA regarding equipment sequence of operation and testing procedures.
  - 3. Through the contractors they supply products to, analyze specified products and verify that the designer has specified the newest most updated equipment reasonable for this project's scope and budget.
  - 4. Review test procedures for equipment installed by factory representatives.
  - 5. Assist in equipment testing per agreements with the Cx Team contractors and subcontractors.
  - 6. Include all special tools and instruments (only available from vendor and specific to a piece of equipment) required for testing equipment according to these Contract Documents, except for stand-alone data logging equipment that may be used by the CA.

## 1.06 PREREQUISITES TO FUNCTIONAL COMPLETION

- A. All Commissioning must be complete prior to Functional Completion, unless approved in writing by the Director's Representative. Exceptions to this are planned system training performed after occupancy and any required seasonal or approved deferred testing. This includes for all systems, but is not limited to:
- 1. Completed and signed start-up and prefunctional checklist documentation.
  - 2. Requested trend log data
  - 3. Submission of final approved TAB report.
  - 4. Completion of all required controls work.
  - 5. Completion of all functional testing.



6. Required training of O&M personnel completed and approved.
  7. Submission of the approved O&M manuals.
  8. All identified deficiencies have been corrected or are approved as exceptions to this milestone by the Director's Representative.
- B. The Director's Representative will determine the date of Functional Completion after reviewing the Commissioning Agent's recommendation for Functional Completion.

## **PART 2 - PRODUCTS (Not Used)**

## **PART 3 - EXECUTION**

### **3.01 REPORTING**

- A. The CA will provide regular reports to the DR with increasing frequency as construction and commissioning progresses. Standard forms will be provided and/or referenced in the Commissioning Plan.
- B. The CA will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.
- C. Testing or review approvals and non-conformance and deficiency reports are made regularly.
- D. A final summary report by the CA will be provided to the DR, focusing on evaluating commissioning process issues and identifying areas where the process could be improved. All acquired documentation, logs, minutes, reports, deficiency lists, communications, findings, unresolved issues, etc., will be compiled in appendices and provided with the summary report. Prefunctional checklists, functional tests and monitoring reports will not be part of the final report, but will be stored in the Commissioning Record in the O&M manuals.

### **3.02 SUBMITTALS**

- A. The CA will provide appropriate contractors with a specific request for the type of submittal documentation the CA requires to facilitate the commissioning work. These requests will be integrated into the normal submittal process and protocol of the construction team. At minimum, the request will include the manufacturer and model number, the manufacturer's printed installation and detailed start-up procedures, full sequences of operation, O&M data, performance data, any performance test procedures, control drawings, wiring diagrams and details of factory tests. In addition, the installation and checkout materials that are shipped inside the equipment and the field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning authority. All documentation requested by the CA will be included by the Cx Team contractors in their O&M manual contributions.

- B. The CA may request additional design narrative from the A/E and the Cx Team Contractors, depending on the completeness of the design intent documentation and sequences provided with the Specifications.
- C. The Commissioning authority will review and approve submittals related to the commissioned equipment for conformance to the Contract Documents as it relates to the commissioning process, to the functional performance of the equipment and adequacy for developing test procedures. This review is intended primarily to aid in the development of functional testing procedures and only secondarily to verify compliance with equipment specifications. The Commissioning authority will notify the DR of items missing or areas that are not in conformance with Contract Documents which may affect the commissioning and which require resubmission.
- D. Submittals to the CA do not constitute compliance for O&M manual documentation. The compilation and submission of O&M manuals is the responsibility of the Contractor. The CA will review and approve individual O&M documents.

### **3.03 START-UP, PREFUNCTIONAL CHECKLISTS AND INITIAL CHECKOUT**

- A. The following procedures apply to all equipment to be commissioned.
- B. The project will require startup and initial checkout to be executed in phases. This phasing will be planned and scheduled in a coordination meeting of the CA, DR and the Cx Team contractors. Results will be added to the Construction Progress Schedule and Commissioning Plan.
- C. General. Prefunctional checklists are important to ensure that the equipment and systems are installed and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. The prefunctional testing for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.
- D. Start-up and Initial Checkout Plan. The CA shall assist the Commissioning Team contractors responsible for startup of any equipment in developing detailed start-up plans. The primary role of the CA in this process is to ensure that there is written documentation that each of the manufacturer-recommended procedures have been completed.
  - 1. The prefunctional checklists and procedures indicate required procedures to be executed as part of startup and initial checkout of the systems and the party responsible for their execution.
  - 2. The prefunctional checklists and tests are provided by the CA to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.
  - 3. Any Cx Team contractor responsible for providing equipment and systems designated for Commissioning, develops the full start-up plan by combining (or adding to) the CA's prefunctional checklists with the manufacturer's detailed start-up and checkout procedures. The Cx Team contractor shall make use of the manufacturer's O&M manual and the normally used field checkout sheets in developing the complete start-up plan. The plan will include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan. The full start-up plan could consist of something as simple as:

- a. The CA's prefunctional checklists.
  - b. The manufacturer's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block added by hand at the end.
  - c. The manufacturer's normally used field checkout sheets.
  4. The contractor submits the full startup plan to the CA for review and approval.
  5. The CA reviews and approves the procedures and the format for documenting them, noting any procedures that need to be added.
  6. The full start-up procedures and the approval form may be provided to the DR for review and approval, depending on management protocol.
- E. Execution of Prefunctional Checklists and Startup.
1. Prior to startup, the Cx Team contractors, subcontractors and vendors schedule startup and checkout with the DR and CA. The performance of the prefunctional checklists, startup and checkout are directed and executed by the Cx Team Contractor, subcontractor or Vendor responsible for the equipment.
  2. The CA shall observe, at minimum, the procedures for each piece of primary equipment, unless there are multiple units, (in which case a sampling strategy may be used as approved by the DR). In no case will the number of units witnessed be less than four nor less than 20% of the total number of identical or very similar units.
  3. For lower-level components of equipment, (e.g., VAV boxes, sensors, controllers), the CA shall observe a sampling of the prefunctional and start-up procedures. The sampling procedures are identified in the commissioning plan.
  4. The Cx Team contractors, subcontractors and vendors shall execute startup and provide the CA with a signed and dated copy of the completed start-up and prefunctional tests and checklists.
  5. Only individuals that have direct knowledge and witnessed that a line item task on the prefunctional checklist was performed shall initial or check that item off.
- F. Deficiencies, Non-Conformance and Approval in Checklists and Startup.
1. The contractors shall clearly list any outstanding items of the initial start-up and prefunctional procedures that were not completed successfully, at the bottom of the procedures form or on an attached sheet. The procedures form and any outstanding deficiencies are provided to the CA within two days of test completion.
  2. The CA reviews the report and submits either a non-compliance report or an approval form to the DR. The installing Cx Team contractors, subcontractors or vendors shall correct all areas that are deficient or incomplete in the checklists and tests in a timely manner, and shall notify the CA as soon as outstanding items have been corrected and resubmit an updated start-up report and a Statement of Correction on the original non-compliance report. When satisfactorily completed, the CA recommends approval of the execution of the checklists and startup of each system to the DR using a standard form.
  3. Items left incomplete, which later cause deficiencies or delays during functional testing may result in back-charges to the responsible party.
- G. Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CA and DR. Beginning system testing before full completion does not relieve the Contractor from fully completing the system, including all prefunctional checklists as soon as possible.

- H. The Cx Team contractors have start-up, prefunctional and functional testing responsibility and are required to complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the Commissioning Agent or Director's Representative.

### **3.04 FUNCTIONAL PERFORMANCE TESTING**

- A. This article applies to all commissioning functional testing for all divisions.
- B. Objectives and Scope.
  - 1. The objective of functional performance testing is to demonstrate that each system is operating according to the documented design intent and Contract Documents. Functional testing facilitates bringing the systems from a state of physical completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems. In general, each system should be operated through all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested.
- C. Test Methods.
  - 1. Functional performance testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance). When a control system is part of the project, functional performance testing may use the controls to monitor the performance and analyze the results using the control system's trend log capabilities or by stand-alone data loggers. The CA may substitute specified methods or require an additional method to be executed, other than what was specified, with the approval of the DR. The CA will determine which method is most appropriate for tests that do not have a method specified.
  - 2. Setup. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Contractor executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Contractor shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.
  - 3. Simulated Conditions. Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
  - 4. Overwritten Values. Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable (i.e., for the above case, the outside air sensor could be heated with a hair blower rather than overwriting the

value, or by altering the appropriate setpoint to see the desired response). Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.

5. Simulated Signals. Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.
  6. Altering Setpoints. Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55F, when the outside air temperature is above 55F, temporarily change the lockout setpoint to be 2F above the current outside air temperature.
  7. Indirect Indicators. Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification is completed during prefunctional testing.
- D. Problem Solving. The CA will recommend solutions to testing problems; however the burden of responsibility to solve, correct and retest problems is with the Cx Team contractors, subcontractors and A/E.

### **3.05 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS**

- A. Documentation.
1. The CA shall witness and document the results of all functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the DR for review and approval and to the Cx Team contractors for review. The CA will include the filled out forms in the Final Commissioning Report.
- B. Non-Conformance.
1. The CA will record the results of the functional test on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the DR.
  2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the CA. In such cases the deficiency and resolution will be documented on the procedure form.
  3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures.
  4. As tests progress and a deficiency is identified, the CA discusses the issue with the executing contractor.
    - a. When there is no dispute on the deficiency and the Contractor accepts responsibility to correct it:
      - 1) The CA documents the deficiency and the Contractor's response and intentions and they go on to another test or sequence. The CA submits the non-compliance reports to the DR for signature, if required. A copy is provided to the Cx Team contractors and CA. The Cx Team contractors correct the deficiency, sign the statement of correction at the bottom of the non-compliance form certifying that the equipment is ready to be retested and send it back to the CA.

- 2) The CA reschedules the test and the test is repeated.
      - b. If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible:
        - 1) The deficiency shall be documented on the non-compliance form with the Cx Team contractor's response and a copy given to the DR and to the Cx Team contractor.
        - 2) Resolutions are made at the lowest management level possible. Other parties are brought into the discussions as needed. Final interpretive authority is with the DR. Final acceptance authority is with the DR.
        - 3) Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the statement of correction on the non-compliance form and provides it to the CA. The Contractor reschedules the test and the test is repeated until satisfactory performance is achieved.
    5. Cost of Retesting.
      - a. The cost for the Cx Team contractor to retest a prefunctional or functional test, if they are responsible for the deficiency, shall be theirs. If they are not responsible, any cost recovery for retesting costs shall be negotiated with the DR.
      - b. For a deficiency identified, not related to any prefunctional checklist or start-up fault, the following shall apply: The CA will direct the retesting of the equipment once at no "charge" to the project for their time. However, the CA's time for a second retest will be charged to the Cx Team contractors.
      - c. The time for the CA to direct, attend or witness any retesting required because a specific prefunctional checklist or start-up test item, reported to have been successfully completed, but determined during functional testing to be faulty, will be back-charged to the Cx Team contractors.
    6. The Contractor shall respond in writing to the CA and DR concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.
    7. The CA retains the original non-conformance forms until the end of the project.
    8. Any required retesting by any contractor shall not be considered a justified reason for a claim of delay or for a time extension by the prime contractor.
  - C. Failure Due to Manufacturer Defect:
    1. If 10 percent, or three units, whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively) due to manufacturing defect, not allowing it to meet its submitted performance specification, all identical units may be considered unacceptable by the DR. In such case, the Contractor shall provide the Director's Representative with the following:
      - a. Within one week of notification from the DR, the Contractor or manufacturer's representative shall examine all other identical units making a record of the findings. Within two weeks of the original notice, a signed and dated, written explanation of the findings, problems, cause of failures, etc. and all proposed solutions shall be provided to the DR. The proposed solutions shall not significantly exceed the specification requirements of the original installation.

- b. The DR will determine whether a replacement of all identical units or a repair is acceptable.
- c. Two examples of the proposed solution will be installed by the Contractor and the installations will be tested for up to one week, upon which the DR and CA will decide whether to accept the solution.
- d. Upon acceptance, the Contractor and/or manufacturer shall replace or repair all identical items, at their expense and extend the warranty accordingly, if the original equipment warranty had begun. The replacement/repair work shall proceed with reasonable speed beginning within one week from when parts can be obtained.

D. Approval:

- 1. The CA notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made later after review by the CA and by the DR, if necessary. The CA recommends acceptance of each test to the DR using a standard form. The DR gives final approval on each test using the same form, providing a signed copy to the CA and the Contractor.

### **3.06 OPERATION AND MAINTENANCE MANUALS**

A. Standard O&M Manuals.

- 1. Additional content and format requirements for the standard O&M manuals are detailed in Section 017716 and individual equipment sections.
- 2. The following O&M manual requirements do not replace O&M manual documentation requirements elsewhere in these specifications.

B. Review and Approvals.

- 1. CA Review and Approval. Prior to substantial completion, the CA shall review the O&M manuals, documentation and redline as-builts for systems that were commissioned, concurrently with the A/E. The CA will communicate concerns about the manuals to the DR. Upon a successful review of the corrections, the CA recommends approval and acceptance of these Sections, with respect to the commissioning, to the DR. The CA also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated. This work does not supersede the A/E's review of the O&M manuals according to the A/E's contract.

### **3.07 TRAINING OF OWNERS OPERATING AND MAINTENANCE PERSONNEL**

A. The Cx Team contractors and CA shall be responsible for training coordination, scheduling and ultimately for ensuring that training is completed.

B. The CA shall be responsible for reviewing and approving the content and adequacy of the training of Owners personnel for commissioned equipment.

- 1. Hands-on training shall include start-up, operation in all modes possible, including manual, shut-down and any emergency procedures and preventative maintenance for all pieces of equipment.
- 2. Training shall occur after functional testing is complete, unless approved otherwise by the DR.

3. Duration of Training: The Cx Team contractor shall provide training on each piece of equipment according to the durations in individual equipment specifications.

### **3.08 DEFERRED TESTING**

- A. Unforeseen Deferred Tests:
  1. If any check or test cannot be completed due to the building structure, required occupancy condition or other deficiency, execution of checklists and functional testing may be delayed upon approval of the DR. These tests will be conducted in the same manner as the seasonal tests as soon as possible. Services of necessary contractors, vendors etc., will be negotiated.
- B. Seasonal Testing:
  1. During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) specified in Section 019113 shall be completed as part of this contract. The CA shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the appropriate contractors, with facilities staff and the CA witnessing. Any final adjustments to the O&M manuals and as-builds due to testing will be made.

### **3.09 WRITTEN WORK PRODUCTS**

- A. The commissioning process generates a number of written work products described in various Sections of the Specifications. The Commissioning Plan lists all the formal written work products, describes briefly their contents, who is responsible to create them, their due dates, who receives and approves them and the location of the specification to create them. In summary, the written products are:
  1. Product Developed By:
    - a. Final Commissioning Plan: CA.
    - b. Commissioning Meeting Minutes: CA.
    - c. Commissioning Schedules: CA with Cx Team contractors and DR.
    - d. Equipment Documentation Submittals: Cx Team contractors.
    - e. Sequence Clarifications: Cx Team contractors, and A/E as needed.
    - f. Prefunctional Checklists: CA.
    - g. Startup and Initial Checkout Plan: Cx Team contractors and CA (compilation of documents).
    - h. Startup and Initial Checkout Forms Filled Out: Cx Team contractors.
    - i. Final TAB Report: TAB.
    - j. Issues Log (deficiencies): CA.
    - k. Commissioning Progress Record: CA.
    - l. Deficiency Reports: CA.
    - m. Functional Test Forms: CA.
    - n. Filled Out Functional Tests: CA.
    - o. O&M Manuals: Cx Team contractors.
    - p. Commissioning Record Book: CA.
    - q. Overall Training Plan: CA and Cx Team contractors.
    - r. Specific Training Agendas: Cx Team contractors.
    - s. Final Commissioning Report: CA.
    - t. Miscellaneous Approvals: CA.

**END OF SECTION**