

SECTION 23 08 00**MECHANICAL SYSTEMS COMMISSIONING****PART 1 - GENERAL****1.1 RELATED DOCUMENTS**

- A. Comply with Division 1 - General Requirements and referenced documents.
- B. Comply with all other Division 23 Sections, as applicable. Refer to other divisions for coordination of work with other portions of Work.

1.2 DESCRIPTION

- A. Commissioning is a systematic process of ensuring that all 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 equipment and systems.
 - 3. Verify that Systems and Operations and Maintenance (O&M) documentation is complete.
 - 4. Verify that the Owner's operating personnel are adequately trained in the O&M of these systems.
- B. The systems to be commissioned include: rooftop AC units, exhaust fans, and all related controls.
- C. Commissioning requires the participation of Division 23 and 26 system installers to ensure that all systems are operating in a manner consistent with the Contract Documents. Division 23 installers shall be familiar with all parts of the commissioning plan issued by the Commissioning Authority (C.A.) and shall execute all commissioning responsibilities assigned to them in the Contract Documents.
- D. Commissioning Team members shall consist of the Commissioning Authority (C.A.), the designated representative of the Owner, the General Contractor (GC, CM or Contractor), the architect and design engineers (particularly the mechanical engineer), the Mechanical Contractor (MC), the Electrical Contractor (EC), the Testing, Adjusting, and Balancing (TAB) representative, the Controls Contractor (CC), and any other installing subcontractors or suppliers of equipment pertinent to the complete installation of Division 23 and 26 Systems intended to be Commissioned. The Owner's

representative for operations and maintenance shall also be a member of the commissioning team.

1.3 COMMISSIONING AUTHORITY

- A. The commissioning authority or agency shall be selected and employed by the building owner. The commissioning agent shall be a licensed professional engineer in the State where the work will be performed, and shall be experienced in the commissioning of mechanical and electrical systems of the type installed in this project. Experience in the construction process, direct digital control systems, Testing, Adjusting, and Balancing; and ASHRAE Guideline 1.1-2007 is mandatory. The commissioning agent shall not be associated with or employed by a mechanical contractor, or equipment supplier.

Commissioning shall be paid for and provided by the District. District shall select the commissioning authority at an early stage of the project and notify the Contractor of the C.A. that shall be employed. Commissioning firm to submit proposal to Owner at same time main proposal is due, refer to Proposal Form 00 30 00. Commissioning firm shall provide pricing where noted on proposal form. Commissioning services shall be performed by one of the following pre-qualified Commissioning Firms:

1. Engineered Air Balance (EAB)
2. Delta T
3. Air Balancing Company (ABC).
4. Farnsworth.

1.4 COMMISSIONING PLAN

- A. Commissioning Plan provides guidance in the execution of the commissioning process. Just after the initial commissioning scoping meeting the CA will provide the plan, which will continue to evolve and expand as the project progresses. The project *Specifications* shall take precedence over the *Commissioning Plan*.
- B. Commissioning Process includes a narrative that provides a brief overview of the typical commissioning tasks during construction and the general order in which they will occur.
1. Commissioning during construction begins with a scoping meeting conducted by the CA where the commissioning process is reviewed with the commissioning team members.
 2. Additional meetings will be required throughout the active construction phase, as scheduled by the CA with necessary parties attending, to plan, scope, coordinate, schedule future activities and resolve problems.
 3. Equipment documentation is submitted to the CA during normal submittals, including detailed start-up procedures.

4. The CA works with the pertinent subcontractors in developing startup plans and startup documentation formats, including prefunctional checklists to be completed, during the startup process.
5. 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.
6. The Subcontractors, under their own direction, execute and document the prefunctional checklists and perform startup and initial checkout. The CA documents that the checklists and startup were completed according to the approved plans. This may include the CA witnessing start-up of selected equipment.
7. The Subcontractors develop proposed specific equipment and system functional performance test (FPT) procedures. The CA will review these procedures and develop the official FPT procedures to be incorporated into the project.
8. The procedures are executed by the Subcontractors, under the direction of, and documented by the CA.
9. Items of non-compliance in material, installation or setup are corrected at the Subcontractor's expense and the system is then retested.
10. The CA reviews the O&M documentation for completeness.
11. Commissioning is intended to be completed before Substantial Completion.
12. The CA reviews, pre-approves and coordinates the training provided by the Subs and verifies that it was completed.
13. Deferred testing is conducted, as specified or as required.

1.5 RESPONSIBILITIES

A. General Contractor (GC):

1. Facilitate the coordination of the commissioning work as outlined by the CA, and with the assistance of the CA, ensure that all commissioning activities are being scheduled into the master construction schedule.
2. Include all costs of commissioning, as outlined herein and elsewhere, in the total contract price.
3. Furnish one (1) copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to equipment to be commissioned to the CA.
4. In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and complete training.
5. Ensure that all subcontractors execute their commissioning responsibilities according to the Contract Documents and schedule.
6. A representative shall attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the Commissioning process.
7. Coordinate the training to be provided to the Owner's personnel.
8. Prepare O&M manuals and systems manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to "as-built" conditions.
9. Warranty Period:

- a. Ensure that Subcontractors execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
- b. Ensure that Subcontractors correct deficiencies and make necessary adjustments to O&M manuals and “as-built” drawings for applicable issues identified in any seasonal testing.

B. Mechanical and Controls Systems Installers:

- 1. Commissioning responsibilities applicable to each of the mechanical and controls (systems installers) of Division 23 are as follows (all references apply to commissioned equipment only):
 - a. Construction and Acceptance Phases:
 - 1) Include the cost of commissioning in the contract price.
 - 2) In each purchase order or subcontract written, include requirements for submittal data, commissioning documentation, Systems and O&M data and training.
 - 3) Attend a commissioning scoping meeting and other meetings necessary to facilitate the Commissioning process.
 - 4) Contractors shall provide the CA with normal cut sheets and shop drawing submittals of all equipment to be commissioned.
 - 5) Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of start-up and functional testing procedures.
 - a) Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, 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, the installation, start-up and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.
 - b) The Commissioning Agent may request further documentation necessary for the commissioning process.
 - 6) Provide a copy of the O&M manuals and submittals of commissioned equipment, through normal channels, to the CA for review and approval.
 - 7) Contractors shall assist (along with the design engineers) 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.

- 8) Preparing proposed specific functional performance test procedures for submission to and consideration of the CA. The CA will use these submittals to prepare finalized test procedures. Subcontractors shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests, as applicable.
 - 9) Develop a full start-up and initial checkout 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.
 - 10) During the startup and initial checkout process, execute the mechanical-related portions of the prefunctional checklists for all commissioned equipment.
 - 11) Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA.
 - 12) Address current A/E punch list items before functional testing. Air TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air related systems.
 - 13) Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. 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.
 - 14) Perform functional performance testing under the direction of the CA for specified equipment. Assist the CA in interpreting the monitoring data, as necessary.
 - 15) Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, and A/E and retest the equipment.
 - 16) Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to "as-built" conditions.
 - 17) Prepare redline "as-built" drawings for all drawings and final "as-builts" for contractor-generated coordination drawings.
 - 18) Provide training of the Owner's operating personnel as specified.
 - 19) Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.
- b. Warranty Period:
- 1) Execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.

- 2) Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

C. Mechanical (Systems Installer) Contractor:

1. The responsibilities of the HVAC mechanical contractor, during construction and acceptance phases in addition to those listed in (A) are:
 - a. Provide startup for all HVAC equipment, except for the building automation control system.
 - b. Assist and cooperate with the TAB contractor and CA by:
 - 1) Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
 - 2) Including cost of sheaves and belts that may be required by TAB.
 - 3) Providing temperature and pressure taps in piping and equipment according to the Construction Documents for TAB and commissioning testing. Verify locations for taps with the CA before installation.
 - c. Prepare a schedule for Division 23 equipment start-up and TAB start and completion for use by the CA. Update the schedule as appropriate.
 - d. Be proactive in seeing that commissioning processes are executed and that the CA has the scheduling information needed to efficiently execute the commissioning process.

D. Controls (Systems Installer) Contractor (CC):

1. The commissioning responsibilities of the controls contractor, during construction and acceptance phases in addition to those listed in (A) are:
 - a. Sequences of Operation Submittals. The Controls Contractor's submittals of control drawings shall include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the specifications. They shall include:
 - 1) An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components and function.
 - 2) All interactions and interlocks with other systems.
 - 3) Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable.
 - 4) Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included, but will generally require additional narrative).

- 5) Start-up sequences.
 - 6) Warm-up mode sequences.
 - 7) Normal operating mode sequences.
 - 8) Unoccupied mode sequences.
 - 9) Shutdown sequences.
 - 10) Capacity control sequences and equipment staging.
 - 11) Temperature and pressure control: setbacks, setups, resets, etc.
 - 12) Detailed sequences for all control strategies, e.g., optimum start/stop, staging, optimization, demand limiting, etc.
 - 13) Effects of power or equipment failure with all standby component functions.
 - 14) Sequences for all alarms and emergency shut downs.
 - 15) Seasonal operational differences and recommendations.
 - 16) Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
 - 17) All sequences shall be written in small statements, each with a number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.
- b. Control Drawings Submittals shall include:
- 1) Control drawings shall have a key to all abbreviations.
 - 2) Control drawings shall contain graphic schematic depictions of each system and each component.
 - 3) Schematics will include the system and component layout of any equipment that the control system monitors, enables or controls, even if the equipment is primarily controlled by packaged or integral controls.
 - 4) Provide a full points list with at least the following included for each point:
 - a) Controlled system.
 - b) Point abbreviation.
 - c) Point description.
 - d) Display unit.
 - e) Control point or setpoint (Yes / No).
 - f) Monitoring point (Yes / No).
 - g) Intermediate point (Yes / No).
 - h) Calculated point (Yes / No).
 - i) Key:
 - (1) Point Description: DB temp, airflow, etc.

- (2) Control or Setpoint: Point that controls equipment and can have its setpoint changed (OSA, SAT, etc.)
 - (3) Intermediate Point: Point whose value is used to make a calculation which then controls equipment (space temperatures that are averaged to a virtual point to control reset).
 - (4) Monitoring Point: Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification.
 - (5) Calculated Point: “Virtual” point generated from calculations of other point values.
- 5) Controls Contractor shall keep the CA informed of all changes to this list during programming and setup.
- c. An updated “as-built” version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.
- d. Assist and cooperate with the TAB contractor in the following manner:
 - 1) Meet with the TAB contractor prior to beginning TAB and review the TAB plan to determine the capabilities of the control system toward completing TAB. Provide the TAB any needed unique instruments for setting terminal unit boxes and instruct TAB in their use (handheld control system interface for use around the building during TAB, etc.).
 - 2) Have all required prefunctional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CA prior to TAB.
 - 3) Provide a qualified technician to operate the controls to assist the TAB contractor in performing TAB, or provide sufficient training for TAB to operate the system without assistance.
- e. Assist and cooperate with the CA in the following manner:
 - 1) Execute the functional testing of the controls system as specified for the controls contractor.
 - 2) Assist in the functional testing of all equipment specified.
- f. Controls contractor shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to functional performance testing, according to the process. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:
 - 1) System name.
 - 2) List of devices.

- 3) Step-by-step procedures for testing each controller after installation, including:
 - a) Process of verifying proper hardware and wiring installation.
 - b) Process of downloading programs to local controllers and verifying that they are addressed correctly.
 - c) Process of performing operational checks of each controlled component.
 - d) Plan and process for calibrating valve and damper actuators and all sensors.
 - e) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
 - 4) A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor or controller has “passed” and is operating within the contract parameters.
 - 5) A description of the instrumentation required for testing.
 - 6) Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CA and TAB contractor for this determination.
 - g. Provide a signed and dated certification to the CA and CM or GC upon completion of the checkout of each controlled device, equipment and system prior to functional testing for each piece of equipment or system, that all system programming is complete as to all respects of the Contract Documents, except functional testing requirements.
 - h. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as specified.
 - i. List and clearly identify on the “as-built” duct and piping drawings the locations of all static and differential pressure sensors (air, water and building pressure).
- E. TAB Contractor. The duties of the TAB contractor, in addition to those listed above are:
1. Submit the outline of the TAB plan and approach for each system and component to the CA prior to starting the TAB. This plan will be developed after the TAB has some familiarity with the control system.
 2. Submitted plan will include:
 - a. Reviewed the construction documents and the systems to sufficiently understand the design intent for each system.

- b. All field checkout sheets and logs to be used that list each piece of equipment to be tested, adjusted and balanced with the data cells to be gathered for each.
 - c. Detailed step-by-step procedures for TAB work for each system and issue.
 - d. Plan for formal deficiency reports (scope, frequency and distribution) and final report.
 - 3. Submit reports of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests to the CA as required.
 - 4. Communicate to the controls contractor all setpoint and parameter changes made or problems and discrepancies identified during TAB, which affect the control system setup and operation.
 - 5. Provide a draft TAB report to the CA. The report should follow the latest reporting recommendations by AABC.
 - 6. Provide the CA with any requested data, gathered, but not shown on the draft reports.
 - 7. Provide final TAB reports in the number required.
- F. Equipment Suppliers:
- 1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner to keep warranties in force.
 - 2. Assist in equipment testing per agreements with Subs.
 - 3. Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these Contract Documents in the base bid price to the Contractor, except for stand-alone data logging equipment that may be used by the CA.
 - 4. Provide information requested by CA regarding equipment sequence of operation and testing procedures.
 - 5. Review test procedures for equipment installed by factory representatives.
- G. Commissioning Agent (CA):
- 1. The CA is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management. The CA may assist with problem-solving non-conformance items or deficiencies, but ultimately that responsibility resides with the general contractor and the A/E. The primary role of the CA is to develop and coordinate the execution of a testing plan, observe and document performance so that systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. Contractor and all subcontractors shall provide all tools or the use of tools to start, checkout and functionally test equipment and systems, to include any specified or required testing equipment needed to conduct these tests.
 - 2. 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 and schedules and technical expertise.

- b. Coordinate the commissioning work and, with the GC, ensure that commissioning activities are being scheduled into the master schedule.
- c. Revise, as necessary, *Commissioning Plan—Construction Phase*.
- d. Plan and conduct a commissioning scoping meeting.
- e. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.
- f. 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.
- g. Review normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, along with A/E reviews.
- h. Assist in the development of prefunctional tests and checklists.
- i. Assist in the development of an enhanced start-up and initial systems checkout plan with Subcontractors.
- 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 the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify Owners project manager of any deficiencies in results or procedures.
- l. Witness all or part of any ductwork testing and cleaning procedures, if required, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify owner's project manager of any deficiencies in results or procedures.
- m. Approve prefunctional tests and checklist completion by reviewing prefunctional checklist reports and by selected site observation and spot-checking.
- n. Approve systems startup by reviewing start-up reports and by selected site observation.
- o. With necessary assistance and review from installing contractors, review the functional performance test procedures for equipment and systems. This may include energy management control system trending, or manual functional testing.

- p. Analyze any functional performance trend logs and monitoring data to verify performance.
 - q. Coordinate, witness and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
 - r. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
 - s. Oversee and approve the training of the Owner's operating personnel.
 - t. Compile and maintain a commissioning record and building systems book(s).
 - u. Review and approve the preparation of the O&M and Systems manuals.
 - v. Provide a final commissioning report.
3. Warranty Period:
- a. Coordinate and supervise required seasonal or deferred testing and deficiency corrections.
 - 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.

1.6 SCHEDULING

- A. The CA will work with the GC according to established protocols to schedule the commissioning activities. The CA will provide sufficient notice to the CM and GC for scheduling commissioning activities.
- B. The GC will integrate all commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

- A. All standard testing equipment required to perform startup and initial checkout and required functional performance testing shall be provided by the applicable Division 23 or 26 contractor for the equipment being tested. For example, the mechanical contractor of Division 23 shall ultimately be responsible for all standard testing

equipment for the HVAC system and controls system in Division 23, except for equipment specific to and used by the TAB firm in their commissioning responsibilities.

- B. Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents, shall be included in the Base Bid price of the Contractor and be left on site.
- C. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in 23 05 93. If not otherwise noted, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration within the past year and a resolution of + or - 0.5°F. Pressure sensors shall have an accuracy of + or - 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals and when dropped or damaged. Calibration tags shall be affixed to the test equipment or certificates of calibration shall be readily available with a copy being furnished to the C.A. for their records.

PART 3 - EXECUTION

3.1 MEETINGS

- A. Scoping Meeting. Within 90 days of commencement of construction, the CA will schedule, plan and conduct a commissioning scoping meeting with the entire commissioning team in attendance. Meeting minutes will be distributed to all parties by the GC. Information gathered from this meeting will allow the CA to revise the *Commissioning Plan* to its "final" version, which will also be distributed to all parties.
- B. Miscellaneous Meetings will be planned and conducted by the CA as required as the construction phase progresses. These meetings will cover coordination, deficiency resolution and planning issues with particular Subcontractors. The CA will plan these meetings and will minimize unnecessary time being spent by Subcontractors, or any other member of the Commissioning Team.

3.2 REPORTING

- A. 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.
- B. Testing or review approvals and non-conformance and deficiency reports are made regularly with the review and testing as described in later sections.

- C. A final summary report by the CA will be provided 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 be part of the final report, and the entire report will be included in the O&M manuals.

3.3 SUBMITTALS

- A. 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 and details of owner contracted tests. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent. All documentation requested by the CA will be included by the Subs in their O&M manual contributions.
- B. Commissioning Agent will be given the opportunity to review all pertinent submittals related to equipment or systems to be commissioned for conformance to the Contract Documents, and more specifically 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 Agent will notify the appropriate persons as requested, of items missing or areas that are not in conformance with Contract Documents as it relates to the commissioning process, and which require resubmission.
- C. CA may request additional design narrative from the A/E and Controls Contractor, depending on the completeness of the design intent documentation and sequences provided with the Specifications.
- D. Submittals sent to the CA do not constitute compliance for O&M manual documentation. The O&M manuals are the responsibility of the Contractor, although the CA will review them.

3.4 START-UP, PREFUNCTIONAL CHECKLISTS AND INITIAL CHECKOUT

- A. The following procedures apply to all equipment to be commissioned. Some systems that are not comprised so much of actual dynamic machinery may have very simplified PCs and startup.
- B. Prefunctional checklists are important to ensure that the equipment and systems are hooked up and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full prefunctional checkout. No sampling strategies are used. 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.
- C. Start-up and Initial Checkout Plans will be required by the CA who shall assist the commissioning team members responsible for startup of any equipment in developing detailed start-up plans for all equipment. 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. Parties responsible for prefunctional checklists and startup are identified in the commissioning scoping meeting and in the checklist forms. Parties responsible for executing functional performance tests are identified in the testing requirements.
 - 1. Checklists indicate required procedures to be executed as part of startup and initial checkout of the systems and the party responsible for their execution.
 - 2. 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 may have more than one trade responsible for its execution.
 - 3. Each Subcontractor responsible for the purchase of each item of equipment shall develop the full start-up plan for that equipment by combining (or adding to) the CA's checklists with the manufacturer's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. 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. Prefunctional checklists developed jointly by the CA and the subcontractors.
 - b. 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. Manufacturer's normally used field checkout sheets.
 - 4. Each Subcontractor shall submit the full startup plan for which they are responsible to the CA for review and approval.
 - 5. CA reviews and approves the procedures and the format for documenting them, noting any procedures that need to be added.

6. Full start-up procedures and the approval form may be provided to the CM for review and approval, depending on management protocol.
- D. Sensor Calibration of all sensors shall be included as part of the prefunctional checklists performed by the Contractors, according to the following procedures:
1. Sensors Without Transmitters, Standard Application type, shall include taking readings with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.

| <u>Sensor</u> | Required Tolerance (+/-) | | Sensor | Required Tolerance (+/-) |
|--|--------------------------|--|-------------------------------|--------------------------|
| Unit wet bulb or dew point | 1.0 Deg.F. | | Flow rates, air | 10%of design |
| Indoor and outdoor air pressure differential | 0.05 Inches W.G. | | Pressures, air | 5% of design |
| Outside air, space air, coil air temps | 1.0 Deg.F. | | Watt-hour, voltage & amperage | 2% |

- E. Execution of Prefunctional Checklists and Startup.
1. Four weeks prior to startup, the Subcontractors and pertinent vendors shall schedule startup and checkout with the GC and CA. The performance of the prefunctional checklists, startup and checkout are directed and executed by the Sub or vendor. When checking off prefunctional checklists, signatures may be required of other Subs for verification of completion of their work.
 2. 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).
 3. For lower-level components of equipment, (e.g., fans, 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. 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 actually performed shall initial or check that item off. It is not acceptable for supervisors to fill out these forms if they have not witnessed the test.
- F. Deficiencies, Non-Conformance and Approval in Checklists and Startup:
1. Subcontractors 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. CA reviews the report and submits either a non-compliance report or an approval form to the Sub or GC. The CA shall work with the Subcontractors and vendors to correct and retest deficiencies or uncompleted items. The CA will involve the GC and others as necessary. The installing 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 using a standard form.

3.5 FUNCTIONAL TESTING

- A. This sub-section applies to all commissioning functional testing for all Divisions.
- B. Objectives and Scope of functional 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 substantial 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, no flow, equipment failure, etc. shall also be tested.
- C. Development of Written Test Procedures shall begin with the CA obtaining all requested documentation and a current list of change orders affecting equipment or systems, including an updated points list, program code, control sequences and parameters. The CA shall then, with the assistance the contractor, develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each Subcontractor or vendor responsible to execute a test, shall provide assistance to the CA in developing the procedures (answering questions about equipment, operation, sequences, etc.). Prior to execution, Subcontractors shall review the tests for feasibility, safety, equipment and warranty protection. The CA may submit the tests to the A/E for review, if requested. The purpose of any given specific test is to verify and document compliance with the stated criteria of acceptance given on the test form.
- D. Test Methods shall include the following:
 1. Functional testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the

- performance and analyzing the results using the control system's trend log capabilities or by stand-alone data loggers. The CA will determine which method is most appropriate for tests that do not have a method specified.
2. Simulated Conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
 3. Altering Set points rather than overwriting sensor values, and when simulating conditions is difficult, altering set points 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.
 4. Setup of each function and testing shall be performed under conditions that simulate actual conditions as close as is practically possible. The Sub 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 Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.
- E. Coordination and Scheduling by the Subcontractors shall provide sufficient notice to the CA regarding their completion schedule for the prefunctional checklists and startup of all equipment and systems. The CA will schedule functional tests through the GC and affected Subcontractors. The CA shall direct, witness and document the functional testing of all equipment and systems. The Subcontractors shall execute all tests. In general, functional testing is conducted after prefunctional testing and startup has been satisfactorily completed. The control system is sufficiently tested and approved by the CA before it is used for TAB or to verify performance of other components or systems. The air balancing and water balancing is completed and debugged before functional testing of air-related or water-related equipment or systems. Testing proceeds from components to subsystems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is checked.

3.6 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

- A. Documentation by the CA shall include witnessing and documenting the results of all functional tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the GC for review. CA will include the filled out forms in the Commissioning Report.
- B. Non-Conformance.
 1. 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 on a standard non-compliance form.

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 Subcontractor accepts responsibility to correct it:
 - 1) CA documents the deficiency and the subcontractor response and intentions and they go on to another test or sequence
 - 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 Subcontractor's response and a copy given to the GC and to the Subcontractor representative assumed to be responsible.
 - 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 A/E. Final acceptance authority is with the Owner.
 - 3) The CA documents the resolution process.
 - 4) 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 CA reschedules the test and the test is repeated until satisfactory performance is achieved.
 5. Cost of Retesting for the Subcontractor 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 GC.
 6. Contractor shall respond in writing to the CA at least as often as commissioning meetings are being scheduled concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.
 7. CA retains the original non-conformance forms until the end of the project.
- C. Approval by the CA shall include notation of each satisfactorily demonstrated function on the test form. CA recommends acceptance of each test using a standard form. The Owner gives final approval on each test using the same form, providing a signed copy to the CA and the Contractor.

3.7 SYSTEMS OPERATION AND MAINTENANCE (O&M) MANUALS

- A. Following System and O&M manual requirements do not replace O&M manual documentation requirements elsewhere in these specifications.
- B. Division 23 shall compile and prepare documentation for all equipment and systems covered in Division 23 and deliver this documentation to the GC for inclusion in the O&M manuals, according to this section, prior to the training of owner personnel.
- C. CA shall receive a copy of the Systems/O&M manuals for review.
- D. Special Control System O&M Manual Requirements shall include, in addition to documentation that may be specified elsewhere, the controls contractor compiling and organizing, at minimum, the following data on the control system in labeled 3-ring binders with indexed tabs:
 - 1. Three (3) copies of the controls training manuals in a separate manual from the O&M manuals.
 - 2. Operation and Maintenance Manuals containing:
 - a. Specific instructions on how to perform and apply all functions, features, modes, etc. mentioned in the controls training sections of this specification and other features of this system. These instructions shall be step-by-step. Indexes and clear tables of contents shall be included. The detailed technical manual for programming and customizing control loops and algorithms shall be included if required in the controls specification section.
 - b. Full as-built set of control drawings.
 - c. Full as-built sequence of operations for each piece of equipment.
 - d. Full points list. In addition to the updated points list required in the original submittal.
 - e. Full print out of all schedules and set points after testing and acceptance of the system.
 - f. Full as-built print out of software program as required.
 - g. Electronic copy on disk of the entire program for this facility if required.
 - h. Marking of all system sensors and thermostats on the as-built floor plan and mechanical drawings with their control system designations.
 - i. Maintenance instructions, including sensor calibration requirements and methods by sensor type, etc.
 - j. Control equipment component submittals, parts lists, etc.
 - k. Warranty requirements.
 - l. Copies of all checkout tests and calibrations performed by the Contractor (not commissioning tests).
 - 3. Manual shall be organized and subdivided with permanently labeled tabs for each of the following data in the given order:

- a. Sequences of operation.
 - b. Control drawings.
 - c. Points lists.
 - d. Controller / module data.
 - e. Thermostats and timers.
 - f. Sensors and DP switches.
 - g. Valves and valve actuators.
 - h. Dampers and damper actuators.
 - i. Program setups (software program printouts).
4. Field checkout sheets and trend logs should be provided to the CA for inclusion in the Commissioning Record Book.
- E. Review and Approval of the commissioning related sections of the Systems and O&M manuals shall be made by the A/E and the CA.

3.8 TRAINING OF OWNER PERSONNEL

- A. GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed.
- B. CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment.
- C. Mechanical Contractor shall have the following training responsibilities:
 - 1. Provide the CA with a training plan two weeks before the planned training.
 - 2. Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to, pumps, heat rejection equipment, air conditioning units, air handling units, fans, controls and water treatment systems, etc.
 - 3. Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
 - 4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
 - 5. The appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment are required. More than one party may be required to execute the training.
 - 6. Controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.

7. Training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
8. Training shall include:
 - a. Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
 - b. A review of the written Systems/O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shutdown, seasonal changeover and any emergency procedures.
 - c. Discussion of relevant health and safety issues and concerns.
 - d. Discussion of warranties and guarantees.
 - e. Common troubleshooting problems and solutions.
 - f. Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.
 - g. Discussion of any peculiarities of equipment installation or operation.
 - h. The format and training agenda in *The HVAC Commissioning Process, ASHRAE Guideline 1.1-2007* is recommended.
 - i. Classroom sessions shall include the use of overhead projections, slides, and video/audio-taped material as might be appropriate.
9. Hands-on training shall include start-up, operation in all modes possible, including manual, shutdown and any emergency procedures and preventative maintenance for all pieces of equipment.
10. Mechanical contractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not *controlled* by the central control system.
11. Duration of Training by the mechanical contractor shall include providing training of sufficient length on each piece of equipment according to the requirements of the preceding specification sections. If not listed in the equipment sections, the following schedule shall be used.

| <u>Hours</u> | <u>System</u> |
|--------------|-------------------|
| <u>6</u> | Rooftop A/C Units |
| <u>4</u> | Exhaust Fans |

D. Controls Contractor shall have the following training responsibilities:

1. Provide the CA with a training plan four weeks before the planned training.
2. Controls contractor shall provide designated Owner personnel training on the control system in this facility. The intent is to clearly and completely instruct the Owner on all the capabilities of the control system.
3. Training manuals shall include the standard operating manual for the system and any special training manuals which shall be provided for each trainee, with three

extra copies left for the O&M manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the O&M manuals. Manuals shall include detailed description of the subject matter for each session. The manuals will cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals *and* in all software displays. Copies of audiovisuals shall be delivered to the Owner.

4. Training will be tailored to the needs and skill-level of the trainees.
5. Trainers will be knowledgeable on the system and its use in buildings. The Owner shall approve the instructor prior to scheduling the training.
6. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
7. Controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
8. There shall be three training sessions:
 - a. Training I - Control System: The first training shall consist of 24 hours of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system.
 - b. Training II - Building Systems: The second session shall be held on-site for a period of 8 hours of actual hands-on training after the completion of system commissioning. The session shall include instruction on:
 - 1) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls and any interface with security and communication systems.
 - 2) Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing setpoints and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
 - 3) All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will actually set-up trends in the presence of the trainer.
 - 4) Every screen shall be completely discussed, allowing time for questions.
 - 5) Use of keypad or plug-in laptop computer at the zone level.

- 6) Use of remote access to the system via phone lines or networks if included.
- 7) Setting up and changing an air terminal unit controller.
- c. Training III - General Overview: The third training will be conducted on-site six months after occupancy and consist of 8 hours of training. The session will be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.
- E. TAB contractor shall have the following training responsibilities:
 - 1. TAB shall meet for 2 hours with facility staff after completion of TAB and instruct them on the following:
 - a. Go over the final TAB report, explaining the layout and meanings of each data type.
 - b. Discuss any outstanding deficient items in control, ducting or design that may affect the proper delivery of air or water.
 - c. Identify and discuss any terminal units, duct runs, diffusers, coils, fans and pumps that are close to or are not meeting their design capacity.
 - d. Discuss any temporary settings and steps to finalize them for any areas that are not finished.
 - e. Other salient information that may be useful for facility operations, relative to TAB.

3.9 WRITTEN WORK PRODUCTS

- A. Written work products of Contractors will consist of the start-up and initial checkout plan described and the filled out start-up, initial checkout, pre-functional, and functional checklists, training plans and records of training. These work products will be supplied to the CA to be included in the final commissioning report.

END OF SECTION