

SECTION 23 0800 - COMMISSIONING OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

- A. The purpose of this section is to specify the Division 23 responsibilities and participation in the Commissioning Process.
- B. Work under this contract shall conform to requirements of Division 01, General Requirements, Conditions of the Contract, and Supplementary Conditions. This specification covers commissioning of mechanical systems which are part of this project.
- C. Commissioning work shall be a team effort to ensure that all mechanical equipment and systems have been completely and properly installed, function together correctly to meet the design intent, and document system performance. Commissioning shall coordinate system documentation, equipment start-up, control system calibration, testing and balancing, and verification and performance testing.
- D. The Commissioning Team shall be made up of representatives from the owner, Design Team, General Contractor (GC), manufacturers, and construction trades. The trades represented on the Commissioning Team shall include, but not be limited to: sheet metal, piping and fitting, controls, test and balance, and electrical. The lead person for each trade who will actually perform or supervise the work is to be designated as the representative to the Commissioning Team. Responsibility for various steps of the Commissioning Process shall be divided among the members of the Commissioning Team, as described in this section.
- E. The Commissioning Authority (CxA) shall have responsibility for coordinating and directing each step of the Commissioning Process.
- F. Mechanical system installation, start-up, testing, balancing, preparation of O&M manuals, and operator training are the responsibility of the Division 23 Contractors, with coordination, observation, verification and commissioning the responsibility of Division 01, Section 01 9113. The 01 9113 Commissioning Process does not relieve Division 23 from the obligations to complete all portions of work in a satisfactory and fully operational manner.
- G. Refer to Division 01, Section 01 9113, for a full list of commissioning related definitions. A few critical definitions are included below:
 - 1. *Commissioning*. A systematic process that provides documented confirmation that specific and interconnected fire and life safety systems function according to the intended design criteria set forth in the project documents and satisfy the owner's operational needs, including compliance requirements of any applicable laws, regulations, codes, and standards requiring fire and life safety systems.
 - 2. *Commissioning Authority (CxA)*. The qualified person, company, or agency that plans, coordinates, and oversees the entire Cx process.
 - 3. *Commissioning Plan*. The document prepared for each project, which identifies the processes and procedures necessary for a successful Cx process.

4. *Commissioning Record.* The complete set of commissioning documentation for the project, which is turned over to the owner at the end of the construction phase.
5. *Functional Testing.* Tests performed to verify compliance with manufacturers' specifications, applicable codes and standards, and the project BOD and OPR.

1.2 RELATED SECTIONS

- A. Division 01 Section 01 9113 - General Commissioning Requirements
- B. Division 21 Section 21 0800 - Commissioning of Fire Suppression
- C. Division 22 Section 22 0800 - Commissioning of Plumbing Systems
- D. Division 23 Section 23 0995 - Commissioning of Integrated Automation
- E. Division 26 Section 26 0800 - Commissioning of Electrical Systems
- F. Individual Division 01, 21, 22, 23, 25, and 26 sections contain requirements related to the commissioning process.

1.3 ROLES AND RESPONSIBILITIES

- A. Refer to Section 01 9113 for Commissioning Authority, Owner, Architect, and General Contractor roles and responsibilities.
- B. Refer to Section 21 0800 for fire protection contractor roles and responsibilities.
- C. Refer to Section 22 0800 for plumbing contractor roles and responsibilities.
- D. Refer to Section 25 0800 for integrated automation contractor roles and responsibilities.
- E. Refer to Section 26 0800 for electrical contractor roles and responsibilities.
- F. Design Team
 1. Provide documentation of initial design concepts and Design Intent based on Owner's program.
 2. Provide mechanical system design parameters and obtain approval of Owner.
 3. Prepare contract documents incorporating Commissioning Specification requirements and description of the electrical systems.
 4. The Design Team shall specify and verify adequate maintenance accessibility for each piece of equipment in shop drawings and the actual installation.
 5. Periodic inspections as part of the Design Team's contract with the Architect and/or Owner.
 6. Review and approve submittals.
 7. Participate in commissioning meetings.
 8. Review Pre-functional Checklists and Functional Performance Test procedures submitted by the Commissioning Authority.
 9. Prepare punch lists.
 10. Review as-built records as required by contract documents. Issue a report noting deficiencies requiring correction to the Commissioning Authority.
 11. Review and comment on final commissioning report.
- G. Mechanical Contractor

1. Include cost to complete commissioning requirements for mechanical systems in the contract price.
2. Include requirements for submittal data, O&M data, and training in each purchase order or sub contract written.
3. Ensure cooperation and participation of all subcontractors.
4. Ensure participation of major equipment manufacturers in appropriate training and testing activities.
5. Attend Construction Phase coordination meeting scheduled by the Commissioning Authority.
6. Conduct mechanical system orientation and inspection when equipment is set.
7. Respond to (in writing) and address items documented in the Contractor Commissioning Issues Log.
8. Notify the GC a minimum of two weeks in advance of system start-up and testing, so CxA may be on site to witness.
9. Notify the GC a minimum of two weeks in advance, of the time for start of the TAB work. Attend the initial TAB meeting for review of the TAB procedures.
10. Submit copies of all test results to the CxA.
11. Complete Pre-Functional Checklists for all equipment.
 - a. If no other system is agreed upon by Commissioning Team, Mechanical Contractor shall be responsible for completion of Pre-Functional Checklists for all equipment for which it issued a purchase order.
 - b. Mechanical Contractor shall coordinate completion of Pre-Functional Checklists with all other contractors that have made connections to equipment for which it issued a purchase order.
 - c. Remedy any deficiencies identified in Pre-Functional Checklists and notify CxA in writing that deficiencies have been addressed.
12. Assist the Commissioning Authority in all Pre-Functional Checklist verifications and Functional Performance Tests.
13. Prepare preliminary schedule for mechanical system orientation and inspections, O&M manual submission, training sessions, pipe and duct system testing, flushing and cleaning, equipment start up, TAB, and task completion for use by the GC and Commissioning Authority. Update schedule as appropriate throughout the construction period.
14. Conduct mechanical system orientation and inspection when equipment is set in place.
15. Keep drawings updated as changes in the field are made, and review with the GC and Commissioning Authority.
16. Gather O&M data on all equipment, and assemble in binders as required by the Commissioning Specification. Submit to GC for review prior to the completion of construction.
17. Participate in, and schedule vendors and Contractors to participate in the training sessions as set up by the GC.
18. Provide written notification to the General Contractor and Commissioning Authority that the following work has been completed in accordance with the contract documents, and that the equipment, systems, and sub-systems are functioning as required.
 - a. HVAC equipment including all fans, air handling units, dehumidification units, ductwork, dampers, terminals, and all Division 23 equipment.
 - b. Refrigeration equipment, pumping systems and heat rejection equipment.
 - c. Fire stopping in the fire rated construction, including fire and smoke damper installation, caulking, gasketing and sealing of smoke barriers.
 - d. Dedicated smoke control systems including stairway pressurization and atrium systems.
 - e. Non-dedicated systems using the air handling units for smoke control.

- f. Fire detection and smoke detection devices furnished under other divisions of this specification as they affect the operation of the smoke control systems.
 - g. That building control systems are functioning to control mechanical equipment and smoke control systems.
19. Submit training syllabus for approval to Commissioning Authority.
20. Participate in, and schedule vendors and Contractors to participate in the training sessions as set up by the GC. Provide site-specific training information on digital media/electronic format (flash drive, CD, DVD). If training is videotaped, provide on digital media/electronic format (flash drive, CD, DVD).
21. Provide a complete set of as-built records to the GC. Hard Copy and Electronic Format (Flash Drive, CD, DVD, etc....) are required.
- H. Test, Adjust, and Balance Contractor
- 1. Include cost for commissioning requirements in the contract price.
 - 2. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
 - 3. Submit the TAB procedures to the GC for review and acceptance.
 - 4. Attend the TAB review meeting scheduled by the GC. Be prepared to discuss the procedures that shall be followed in testing, adjusting and balancing the HVAC system.
 - 5. Participate in training sessions as scheduled by the GC.
 - 6. At the completion of the TAB work, and submittal of final TAB report, notify the Mechanical Contractor.
 - 7. Participate in verification of the TAB report, which will consist of repeating any selected measurement contained in the TAB report where required by the Commissioning Authority for verification or diagnostic purposes.
- I. Integrated Automation Contractors
- 1. Include cost for commissioning requirements in the contract price, including assisting the Commissioning Authority with implementation of Functional Test Procedures and reviewing control system operation with the Commissioning Authority.
 - 2. Review design for controllability with respect to selected manufacturer's equipment:
 - a. Verify proper hardware specification exists for functional performance required by specification and sequence of operation.
 - b. Verify proper safeties and interlocks are included in design.
 - c. Verify proper sizing of control valves and actuators based on design pressure drops. Verify control valve authority to control coil properly.
 - d. Verify proper sizing of control dampers. Verify damper authority to control air stream. Verify proper damper positioning for mixing to prevent stratification. Verify actuator vs. damper sections for smooth operation.
 - e. Verify proper selection of sensor ranges.
 - f. Clarify all questions of operation.
 - 3. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
 - 4. Provide the following submittals to the GC:
 - a. Hardware and software submittals.
 - b. Control panel construction shop drawings.
 - c. Narrative description of each control sequence for each piece of equipment controlled.

- d. Diagrams showing all control points, sensor locations, point names, actuators, controllers and, where necessary, points of access, superimposed on diagrams of the physical equipment.
 - e. Logic diagrams showing the logic flow of the system.
 - f. A list of all control points, including analog inputs, analog outputs, digital inputs, and digital outputs. Include the values of all parameters for each system point. Provide a separate list for each stand-alone control unit.
 - g. A complete control language program listing including all software routines employed in operating the control system. Also provide a program write-up, organized in the same manner as the control software. This narrative shall describe the logic flow of the software and the functions of each routine and sub-routine. It should also explain individual math or logic operations that are not clear from reading the software listing.
 - h. Hardware operation and maintenance manuals.
 - i. Application software and project applications code manuals.
5. Verify proper installation and performance of controls/BAS hardware and software provided by others.
 6. Integrate installation and programming schedule with construction and commissioning schedules.
 7. Provide thorough training to operating personnel on hardware operations and programming, and the application program for the system.
 8. Demonstrate system performance to Commissioning Authority including all modes of system operation (e.g. normal, abnormal, and emergency).
 9. Provide control system technician for use during Pre-Functional Checklists and Functional Performance Testing.
 10. Provide system modifications as required.
 11. Provide support and coordination with TAB contractor on all interfaces between their scopes of work. Provide all devices, such as portable operator terminals, for TAB use in completing TAB procedures.
 12. Provide trend logs as required to facilitate the Commissioning Process.

J. Equipment Manufacturers and Miscellaneous Contractors

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

1.4 SCOPE OF WORK

A. Commissioning work of Division 23 shall include, but not be limited to:

1. Testing and start-up of the equipment.
2. Logging in and checking the WCxS at least once a week for outstanding items.
3. Completion of Pre-Functional Checklists on the WCxS.
4. Testing, adjusting and balancing of hydronic and air systems.
5. Cooperation with the Commissioning Authority.
6. Providing qualified personnel for participation in commissioning tests, including seasonal testing required after the initial testing.
7. Providing equipment, materials, and labor as necessary to correct construction and/or equipment deficiencies found during the Commissioning Process.

8. Providing operation and maintenance manuals and as-built drawings to the Commissioning Authority for verification.
 9. Providing training and demonstrations for the systems specified in this Division.
- B. The work included in the Commissioning Process involves a complete and thorough evaluation of the operation and performance of all components, systems, and sub-systems. The following equipment and systems shall be evaluated:
1. Air Handling Units
 2. Chiller
 3. Cooling tower
 4. Cooling system pumps
 5. Heat exchangers and associated pumps
 6. Steam PRV station
 7. Space pressurization for critical rooms including operating rooms, interventional rooms and isolation rooms
 8. Atrium smoke exhaust
 9. Unit heaters (15 percent sampling)
 10. Refrigerant purge exhaust
 11. Variable air volume terminals (15 percent sampling up to 60 VAV boxes)
 12. Temperature control systems
 13. Vertical transportation
 14. Pneumatic tube system
 15. Refrigeration systems including clinical refrigerators and freezers.
 16. Air distribution systems, including ductwork, fittings, insulation, fire dampers, diffusers, grilles, balancing dampers, sound attenuators, etc.
 17. Hydronic distribution systems, including piping, valves, fittings, insulation, air separators, expansion tanks, etc.
 18. Fire alarm and fire protection devices.
 19. Fire alarm interface with HVAC, life safety and elevators.
 20. Fire protection system for the South Addition Main Entrance Canopy.
 21. Fire protection system for the CT and MRI rooms.
- C. Timely and accurate documentation is essential for the Commissioning Process to be effective. Documentation required as part of the Commissioning Process shall include but not be limited to:
1. Commissioning Process Reports, which may include the following:
 - a. Commissioning Field Reports
 - b. Design Team Issues Log
 - c. Contractor Commissioning Issues Log from the WCxS
 - d. Meeting Minutes
 2. Pre-start, and start-up procedures
 3. Pre-Functional Checklists on the WCxS
 4. Functional Performance Tests on the WCxS
 5. Training agenda and materials
 6. As-built records
 7. Final commissioning report
 8. Operation and maintenance (O&M) manuals
- D. Detailed testing maybe performed on all installed equipment and systems to ensure that operation and performance conform to contract documents. All tests shall be witnessed by the Commissioning Authority. The following testing is required as part of the Commissioning process:

1. Pre-Functional Checklists (PFC) are comprised of a full range of checks and tests to determine that all components, equipment, systems, and interfaces between systems operate in accordance with contract documents. Verification is completed by the Division 22, 23 and 26 contractors and documented using Pre-Functional Checklists.
 2. Functional Performance Tests (FPT) shall determine if the HVAC system is operating in accordance with the design intent. This includes all operating modes, interlocks, control responses, and specific responses to abnormal or emergency conditions.
- E. Comprehensive training of O&M personnel shall be performed by the Mechanical Contractor, and where appropriate, by other sub-contractors, and vendors prior to turnover of building to the owner. The training shall include classroom instruction, along with hands-on instruction on the installed equipment and systems.

1.5 DOCUMENTATION

- A. The Commissioning Authority shall oversee and maintain the development of the document process. The GC shall facilitate project documentation through the web-based commissioning software. The commissioning documentation shall include, but not be limited to, the following:
1. Commissioning Plan
 2. Commissioning Schedule
 3. Document Request Log
 4. Commissioning RFIs
 5. Commissioning Field Reports on the WCxS
 6. Design Team Issues Log on the WCxS
 7. Contractor Commissioning Issues Log on the WCxS
 8. Pre-Functional Checklists on the WCxS
 9. Functional Performance Tests on the WCxS
 10. See 01 9113 for additional information on the commissioning documentation.
- B. See 01 9113 for additional information on the commissioning documentation.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

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

2.2 TEST EQUIPMENT – PROPRIETARY

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

PART 3 - EXECUTION

3.1 GENERAL

- A. A pre-construction meeting of all Commissioning Team members shall be held at a time and place designated by the owner. The purpose shall be to familiarize all parties with the Commissioning Process, and to ensure that the responsibilities of each party are clearly understood.
- B. The Contractor shall complete all phases of work so the systems can be started, tested, balanced, and commissioning procedures undertaken. This includes the complete installation of all equipment, materials, pipe, duct, wire, insulation, controls, etc., per the contract documents and related directives, clarifications, and change orders.
- C. A Commissioning Plan shall be developed by the Commissioning Authority. The Contractor shall assist the Commissioning Authority in preparing the Commissioning Plan by providing all necessary information pertaining to the actual equipment and installation. If contractor-initiated system changes have been made that alter the Commissioning Process, the Commissioning Authority shall notify the Owner.
- D. The Contractor is to complete the Work in a sequence that allows for systemic and holistic functional testing rather than piecemeal testing. This includes BAS and SCADA integration.
- E. Acceptance procedures are normally intended to begin prior to completion of a system and/or sub-systems, and shall be coordinated with the Division 23 contractor. Start of acceptance procedures before system completion does not relieve the contractor from completing those systems as per the schedule.

3.2 PARTICIPATION IN COMMISSIONING

- A. The Contractor shall provide skilled technicians to start-up and debug all systems within Division 15. These same technicians shall be made available to assist the Commissioning Authority in completing the commissioning program. Work schedules, time required for testing, etc., shall be requested by the Commissioning Authority and coordinated by the contractor. Contractor shall ensure that the qualified technician(s) are available and present during the agreed upon schedules and of sufficient duration to complete the necessary tests, adjustments, and/or problem resolutions.
- B. System performance problems and discrepancies may require additional technician time, Commissioning Authority time, reconstruction of systems, and/or replacement of system components. The additional technician time shall be made available for subsequent commissioning periods until the required system performance is obtained.
- C. The Commissioning Authority reserves the right to question the appropriateness and qualifications of the technicians relative to each item of equipment, system, and/or sub-system. Qualifications of technicians shall include expert knowledge relative to the specific equipment involved and a willingness to work with the Commissioning Authority. Contractor shall provide adequate documentation and tools to start up and test the equipment, system, and/or sub-system.

3.3 DEFICIENCY RESOLUTION

- A. In some systems, maladjustments, misapplied equipment, and/or deficient performance under varying loads will result in additional work being required to commission the systems. This work

shall be completed under the direction of the Owner, with input from the contractor, equipment manufacturer, and Commissioning Authority. Whereas all members shall have input and the opportunity to discuss, debate, and work out problems, the Owner shall make final determination over any additional required work to achieve performance.

- B. Corrective work shall be completed in a timely fashion to permit the completion of the Commissioning Process. Experimentation to demonstrate system performance may be permitted. If the Commissioning Authority deems the experimentation work to be ineffective or untimely as it relates to the Commissioning Process, the Commissioning Authority shall notify the Owner, indicating the nature of the problem, expected steps to be taken, and suggested deadline(s) for completion of activities. If the deadline(s) pass without resolution of the problem, the Owner reserves the right to obtain supplementary services and/or equipment to resolve the problem. Costs incurred to solve the problems in an expeditious manner shall be the contractor's responsibility.
- C. The Owner's contract with the Commissioning Authority includes up to two Functional Performance Tests of each piece of equipment or system included in the commissioning scope. Commissioning Authority time and expenses required for retests beyond two, if required, due to incomplete installation or otherwise, will be paid by the Owner and reimbursed by the contractor.

3.4 ADDITIONAL COMMISSIONING

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

3.5 SEASONAL COMMISSIONING

- A. Seasonal commissioning pertains to testing under full load conditions during peak heating and peak cooling seasons, as well as part load conditions during off-peak periods. Initial commissioning shall be done as soon as contract work is completed, regardless of season. Subsequent commissioning may be undertaken at any time thereafter to ascertain adequate performance during the different peak and off-peak conditions. Each contractor and manufacturer shall be responsible to participate in the initial and the alternate peak and off-peak tests of the systems as required to demonstrate performance.

3.6 CONSTRUCTION PHASE OBSERVATION

- A. Scope of Construction Phase Observation
 - 1. The Commissioning Authority will conduct periodic observations during the Construction Phase to monitor progress and compliance with the design intent and contract documents. It is the responsibility of the contractor to address the issues noted on the Issues Log and notify Commissioning Authority of completion.
 - 2. Commissioning Authority observations will coincide with Design Team observations and are not intended to take the place of this work.
- B. Documentation and Reporting
 - 1. Issues identified by the Commissioning Authority during Construction Phase will be documented on the WCxS and distributed to Commissioning Team members.

2. Progress during the Construction Phase will also be documented by the Commissioning Authority using Commissioning Process Reports.

3.7 ACCEPTANCE PROCEDURES

A. Pre-Functional Checklists

1. Pre-Functional Checklist Scope

- a. Tests and verifications included in the Pre-Functional Checklists shall determine if all components, equipment, systems, and interfaces between systems are installed and are ready to operate in accordance with contract documents.

2. Pre-Functional Checklist Roles and Responsibilities

- a. The Commissioning Authority shall be responsible for creating the Checklists, which will be completed by the installing contractors and then verified (via spot checking and Functional Performance Testing). Participating contractors, manufacturers, etc. shall include all costs to do the work involved in these tests in their proposals. The following is a list of tasks and supporting information that shall be required:
- b. The Mechanical Contractor shall provide the services of a technician(s) who is (are) familiar with the construction and operation of the applicable system. Provide access to the contract plans, shop drawings, and equipment cut sheets of all installed equipment.
- c. The controls contractor shall provide the services of a controls engineer who is familiar with the details of the project. Provide details of the control system, schematics, and a narrative description of control sequences of operation.
- d. The electrical contractor shall provide a foreman electrician familiar with the electrical interlocks, interfaces with emergency power supply, and interfaces with alarm and life-safety systems. Provide access to the contract plans, and all as-built schematics of sub-systems, interfaces, and interlocks.

3. Documentation and Reporting Requirements

- a. Pre-Functional Checklists shall be provided for each component, piece of equipment, system, and sub-system, including all interfaces, interlocks, etc. Each item to be tested shall have a different entry line with space provided for comments. The checklists will include spaces for each party to sign off on.
- b. Completed checklists shall be submitted to the Commissioning Authority for acceptance and inclusion in the commissioning report.

4. Acceptance of Pre-Functional Checklists

- a. The Commissioning Authority will select, at random, 10 percent of the checklists for verification.
- b. If 10 percent or more of the checklists are found to be inaccurate for each system or equipment type, all of the checklists for that system or equipment type will be rejected. Complete, accurate checklists will need to be resubmitted.

B. Test, Adjust, and Balance Verification

1. The Commissioning Authority shall select, at random, 10 percent of the report data for verification.

2. The TAB contractor shall be given sufficient advance notice of the date of field verification. However, they shall not be informed in advance of the data points to be verified.
3. Failure of an item is defined as:
 - a. For all readings other than sound, a deviation of more than 10 percent.
 - b. For sound pressure readings, a deviation of 3 decibels. (Note: variations in background noise must be considered).
4. A failure of more than 10 percent of the selected items shall result in the rejection of the final TAB report.

C. Functional Performance Testing

1. Scope of Functional Performance Testing
 - a. Functional Performance Tests shall determine if equipment, system, and/or sub-system is operating in accordance with the final design intent. This includes all operating modes, interlocks, control responses, and specific responses to abnormal or emergency conditions. The following is a list of test examples:
 - 1) Determine capability of chilled water system to deliver chilled water at the design supply temperature, and required rate of flow.
 - 2) Determine capacity of electric heating system to deliver heating at the design temperature.
 - 3) Determine the ability of the HVAC unit to deliver the cooling and/or heating services to the distribution system, at the design supply air temperature, required static pressure, and proper outside air ventilation rate.
2. Functional Performance Test Report
 - a. Detailed procedures for each series of tests will be developed by the Commissioning Authority for review and acceptance by the GC and Owner. The procedures shall include samples of the data sheets that will be part of the reports.
 - b. The Functional Performance Test Report will be integrated as part of the WCxS.
3. Participants in Functional Performance Tests
 - a. Participants in the Functional Performance Tests shall be the same as those listed in the Pre-Functional Checklists.
4. Functional Performance Test Procedures
 - a. The Commissioning Authority shall supervise and direct all Functional Performance Tests.
 - 1) Set the system equipment (i.e. chiller, boiler, pumps, fans, etc.) into the operating mode to be tested (i.e. normal shut-down, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).
 - 2) The Commissioning Authority shall inspect and verify the position of each device and interlock identified in the test procedure. Each item shall be signed off as acceptable (yes) or failed (no).
 - 3) This test shall be repeated for each operating cycle that applies to the mechanical system being tested.

- 4) Operating checks shall include all safety cutouts, alarms, and interlocks with smoke control and life safety systems during all modes of operation of the mechanical system.
 - 5) If during a test an operating deficiency is observed, appropriate comments will be added to the Test Procedure form and the Issues Log.
 - 6) Confirmation of the TAB results shall be verified utilizing the Building Automation System. This shall include, but not be limited to, the following:
 - a) Verify supply and return flow rates for VAV and constant volume systems in all modes of operation of the HVAC system.
 - b) Verify operation of the terminal units in both heating and cooling cycles.
 - c) Verify minimum outdoor air intake in all modes of operation and at minimum and maximum total airflow rates.
 - d) Verify building pressurization.
 - e) Verify total exhaust airflow, and total outdoor air intake.
 - 7) Verification of the proper responses of BAS system controllers and sensors shall be as follows:
 - a) For each controller or sensor, record the indicated BAS system reading, and the test instrument reading.
 - b) If the initial test indicates that the test reading is outside of the control range of the installed device, the calibration of the installed device shall be checked and adjusted as required. The deficient device shall be re-tested and the results recorded on the Functional Performance Test form on the WCxS.
- b. If deficiencies are identified during Functional Performance Testing, the General Contractor will be notified, and action taken to remedy the deficiency. The final Functional Test Procedure forms will be reviewed by the Commissioning Authority to determine if testing is complete and the system is functioning in accordance with the contract documents.
5. Documentation and Reporting Requirements
- a. All measured data, data sheets, and a comprehensive summary, describing the operation of the HVAC system at the time of testing shall be submitted to the Commissioning Authority.
 - b. A preliminary Functional Performance Test report shall be prepared by the Commissioning Authority and submitted to the Design Team for review. Any identified deficiencies need to be evaluated by the Design Team and General Contractor to determine if they are part of the contractor's or sub-contractor's contractual obligations. Construction deficiencies shall be corrected by the responsible contractor(s), and the specific Functional Performance Test repeated.
 - c. If it is determined that the HVAC system is constructed in accordance with the contract documents, and the performance deficiencies are not part of the contract documents, the Owner must decide whether any required modifications needed to bring the performance of the HVAC system up to the finalized design intent shall be implemented, or if the test shall be accepted as submitted. If corrective work is performed, the owner shall determine if a portion or all required Functional Performance Tests should be repeated, and a revised report submitted.

3.8 SYSTEMS MANUAL:

A. The Systems Manual shall be submitted in paper AND/OR electronic format and shall contain the following major sections:

1. System Descriptions:

a. Each major system shall be described, typewritten, in general terms, including major components, interconnections, theory of operation, theory of controls, unusual features and major safety precautions. This information should correlate with information provided in the manufacturers' instructions book. This section shall include, but not be limited to, the following data:

- 1) Detailed description of each system and each of its components showing piping, valves, controls, and other components, with diagrams and illustrations where applicable.
- 2) Wiring and control diagrams with data to explain detailed operation and control of each component.
- 3) Control sequences describing start-up, all modes of operation, and shut down.
- 4) Corrected shop drawings.
- 5) Approved product data including all performance curves and rating data.
- 6) Copies of approved certifications and laboratory or factory test reports (where applicable).
- 7) Copies of warranties.

b. System diagrams, described in the following section, shall be incorporated in the appropriate systems descriptions. These should be reduced in size or folded to usefully fit into the manual.

2. Operating Instructions:

a. Condensed, typewritten, suitable for posting, instructions shall be provided for each major piece of equipment. Where more than one (1) common unit is installed, one instruction is adequate. The instructions shall provide procedures for:

- 1) Starting up the equipment/system
- 2) Shutting down the equipment/system
- 3) Operating the equipment in emergency or unusual conditions
- 4) Safety precautions
- 5) Trouble shooting suggestions
- 6) Other pertinent data applicable to the operation of particular systems or equipment

b. The instructions shall be suitable for posting adjacent to the equipment concerned.

c. The contractor shall provide instructions for (at minimum):

- 1) Air Handling Units
- 2) Chillers
- 3) HVAC pumps
- 4) Boilers
- 5) Heating hot water pumps
- 6) Make-up air units
- 7) Café Exhaust

- 8) Classroom and lab exhaust (representative sampling)
- 9) Variable air volume terminals (25 percent sampling, with 100 percent of critical space VAVs)
- 10) Temperature control systems
- 11) Air and hydronic test and balance
- 12) Air distribution systems, including ductwork, fittings, insulation, fire dampers, diffusers, grilles, balancing dampers, sound attenuators, etc.
- 13) Hydronic distribution systems, including piping, valves, fittings, insulation, air separators, expansion tanks, etc.
- 14) Domestic hot water heaters

3. Ongoing and Preventive Maintenance:

- a. Condensed, typewritten procedures for recommended ongoing and preventive maintenance actions shall be provided for each category of equipment/system listed above. This information shall include, but not be limited to the following:

- 1) Maintenance and overhaul instructions.
- 2) Lubricating schedule including type, grade, temperature, and frequency range.
- 3) Parts list, including source of supply and recommended spare parts.
- 4) Name, address, and 24 hour telephone number of each subcontractor who installed equipment and systems, and local representative for each type of system.
- 5) Other pertinent data applicable to the maintenance of particular systems or equipment.

- b. These recommended preventive maintenance actions shall be categorized by the following recommended frequencies:

- 1) Weekly
- 2) Monthly
- 3) Quarterly
- 4) Semi Annual
- 5) Annual
- 6) Other

B. Posted Operating Instructions and Diagrams:

1. Operating Instructions:

- a. Copies of operating instructions provided in the Systems Manual shall be posted in the near vicinity of each piece of applicable equipment. The instructions shall be mounted neatly in frames under Plexiglas, where they can be easily read by operating personnel. Instructions mounted outdoors shall be suitably protected from weather.

2. Posted Systems Diagrams:

- a. Simplified one (1) line diagrams of the systems listed shall be developed using AutoCAD and posted neatly under Plexiglas in the main or most appropriate equipment room for easy reference by operating and maintenance personnel. These drawings shall be done in a professional manner which is acceptable to the Owner. The diagrams shall show each component including all valves installed in

the system, with name and identifying number. If space does not permit valve numbers on the diagrams, valve charts shall be provided. Explanatory notes, where needed, shall be provided.

- 1) HVAC controls diagrams
- 2) Hydronic distribution systems
- 3) Air handling/ventilation systems
- 4) Domestic water systems
- 5) Other systems as applicable

- b. These diagrams shall be suitable for reduction in size and use in the Systems Manual system descriptions previously covered.

3.9 SYSTEMS TRAINING:

- A. The Mechanical Contractor, and appropriate sub-contractors, shall provide comprehensive systems instruction on building systems prior to delivery. The instruction shall include classroom instruction delivered by competent instructors based upon the contents of the Systems Manual. Emphasis shall be placed upon overall systems diagrams and descriptions, and how system components interact. The classroom instruction shall also include detailed equipment instruction by qualified manufacturer's representatives for which operating instructions are provided. The manufacturer's representative training shall emphasize operating instructions and preventive maintenance as described in the Systems Manual. At a minimum, the training sessions shall cover the following items:

1. Types of installed systems
2. Theory of operation
 - a. Design intent
 - b. Occupied vs. unoccupied or partial occupancy
 - c. Seasonal modes of operation
 - d. Emergency conditions and procedures
 - e. Comfort conditions
 - f. Indoor air quality
 - g. Energy efficiency
 - h. Other issues important to facility operation
3. System operations
4. Use of control system
 - a. Sequence of operation
 - b. Problem indicators
 - c. Diagnostics
 - d. Corrective actions
5. Service, maintenance, diagnostics and repair
6. Use of reports and logs
7. Troubleshooting, investigation of malfunctions, and determining reasons for the problem

- B. Each classroom training period shall be followed by an inspection, explanation, and demonstration of the system by the instructors. The applicable equipment shall be demonstrated including system startup and shutdown, with the exception of sprinkler systems.

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- C. The contractor shall be responsible for organizing, arranging, and delivering this instruction in an efficient and effective manner on a schedule agreeable to the Owner.
- D. The contractor shall provide, at or before substantial completion, a proposed agenda and schedule of the above training for approval by the Commissioning Authority and the Owner.

END OF SECTION 23 0800