SECTION 230800 - COMMISSIONING OF HVAC

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

LEED-NC Prerequisite EA 1 requires fundamental commissioning of the building energy systems. If applying for LEED certification, review LEED requirements and revise the Text to meet specific requirements.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes commissioning process requirements for HVAC&R systems, assemblies, and equipment.

B. The systems to be commissioned are listed in Section 019113.

C. Commissioning requires the participation of Division 23 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirement and coordination are detailed in Division 1. Division 23 shall be familiar with all parts of Division 1 and the commissioning plan issued by the Commissioning Agent (CxA) and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.3 DEFINITIONS

A. BAS: Building Automation System.

B. BASC: Building Automation System Contractor.

C. CM: Construction Manager.

D. Commissioning Plan: A document that outlines the organization, schedule, allocation of resources, and documentation requirements of the commissioning process.

E. CxA: Commissioning Authority.
F. HVAC: Heating, Ventilation, and Air Conditioning.


H. O&M: Operations and Maintenance.

I. Systems, Subsystems, Equipment, and Components: Where these terms are used together or separately, they shall mean "as-built" systems, subsystems, equipment, and components.

J. TAB: Testing and Balancing.

1.4 CONTRACTOR'S RESPONSIBILITIES

A. Perform commissioning tests at the direction of the CxA.

B. Attend construction phase controls coordination meeting.

C. Attend testing, adjusting, and balancing review and coordination meeting.

D. Participate in HVAC&R systems, assemblies, equipment, and component maintenance orientation and inspection as directed by the CxA.

E. Provide information requested by the CxA for final commissioning documentation.

F. Provide measuring instruments and logging devices to record test data, and provide data acquisition equipment to record data for the complete range of testing for the required test period.

1.5 RESPONSIBILITIES

A. Mechanical, Controls and TAB Contractors. The commissioning responsibilities applicable to each of the mechanical, controls and TAB contractors of Division 23 are as follows (all references apply to commissioned equipment only):

1. Construction and Acceptance Phases
   a. Include and itemize the cost of commissioning in the contract price.
   b. In each purchase order or subcontract written, include requirements for submittal data, commissioning documentation, O&M data and training.
   c. Attend a commissioning scoping meeting and other meetings necessary to facilitate the Cx process.
   d. Contractors shall provide the CxA with normal cut sheets and shop drawing submittals of commissioned equipment.
   e. Provide additional requested documentation, prior to normal O&M manual submittals, to the CxA for development of start-up and functional testing procedures.

   1) 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.

2) The Commissioning Agent may request further documentation necessary for the commissioning process.

3) This data request may be made prior to normal submittals.

f. Provide a copy of the O&M manuals and submittals of commissioned equipment, through normal channels, to the CxA for review and approval.

g. 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.

h. Provide limited assistance to the CxA in preparing the specific functional performance test procedures as specified in Division 01 Section "General Commissioning Requirements". Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.

i. Develop a full start-up and initial checkout plan using manufacturer’s start-up procedures and the prefunctional checklists from the CxA for all commissioned equipment. Submit to CxA for review and approval prior to startup. Refer to Section 019113 for further details on start-up plan preparation.

j. During the startup and initial checkout process, execute the mechanical-related portions of the prefunctional checklists for all commissioned equipment.

k. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CxA.

l. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.

m. 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.

n. Provide skilled technicians to perform functional performance testing under the direction of the CxA for specified equipment in Section 019113 and 239950-3. Assist the CxA in interpreting the monitoring data, as necessary.

o. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxA, CM and A/E and retest the equipment.

p. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.

q. During construction, maintain as-built red-line drawings for all drawings and provide final CAD record drawings for owner and contractor-generated coordination drawings. Update after completion of commissioning (excluding deferred testing).

r. Provide training of the Owner’s operating staff using expert qualified personnel, as specified.
s. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

2. Warranty Period

a. Execute seasonal or deferred functional performance testing, witnessed by the CxA, according to the specifications.
b. Correct deficiencies and make necessary adjustments to O&M manuals and record drawings for applicable issues identified in any seasonal testing.

B. Mechanical Contractor. The responsibilities of the HVAC mechanical contractor, during construction and acceptance phases in addition to those listed in Division 23 are:

1. Provide startup for all HVAC equipment, except for the building automation control system.
2. Assist and cooperate with the TAB contractor and CxA by:
   a. Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
   b. Including cost of sheaves and belts that may be required by TAB.
   c. Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Providing an approved plug.
   d. Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.

3. Install a P/T plug at each water sensor which is an input point to the control system.
4. List and clearly identify on the as-built drawings the locations of all air-flow stations.
5. Prepare a preliminary schedule for Division 23 pipe and duct system testing, flushing and cleaning, equipment start-up and TAB start and completion for use by the CxA. Update the schedule as appropriate.
6. Notify the Owner, CM or CxA depending on protocol, when pipe and duct system testing, flushing, cleaning, startup of each piece of equipment and TAB will occur. Be responsible to notify the Owner, CM or CxA, ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed and that the CxA has the scheduling information needed to efficiently execute the commissioning process.

C. Controls Contractor. The commissioning responsibilities of the controls contractor, during construction and acceptance phases in addition to those listed in Division 23 are:

1. 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:
   a. An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components and function.
   b. All interactions and interlocks with other systems.
c. 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.

d. Written sequences of control for packaged controlled equipment. (Equipment manufacturers’ stock sequences may be included, but will generally require additional narrative).

e. Start-up sequences.

f. Warm-up mode sequences.

g. Normal operating mode sequences.

h. Unoccupied mode sequences.

i. Shutdown sequences.

j. Capacity control sequences and equipment staging.

k. Temperature and pressure control: setbacks, setups, resets, etc.

l. Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.

m. Effects of power or equipment failure with all standby component functions.

n. Sequences for all alarms and emergency shut downs.

o. Seasonal operational differences and recommendations.

p. Initial and recommended values for all adjustable settings, set points 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.

q. Schedules, if known.

r. To facilitate referencing in testing procedures, 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.

2. Control Drawings Submittal

a. The control drawings shall have a key to all abbreviations.

b. The control drawings shall contain graphic schematic depictions of the systems and each component.

c. The 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.

d. Provide a full points list with at least the following included for each point:

1) Controlled system
2) Point abbreviation
3) Point description
4) Display unit
5) Control point or set point (Yes / No)
6) Monitoring point (Yes / No)
7) Intermediate point (Yes / No)
8) Calculated point (Yes / No)

  a) Key:
  b) Point Description: DB temp, airflow, etc.
  c) Control or Set point: Point that controls equipment and can have its set point changed (OSA, SAT, etc.)
d) 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).

e) Monitoring Point: Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification.

f) Calculated Point: “Virtual” point generated from calculations of other point values.

9) The Controls Contractor shall keep the CA informed of all changes to this list during programming and setup.

3. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.

4. Assist and cooperate with the TAB contractor in the following manner:

   a. 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.).

   b. For a given area, have all required prefucntional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CxA prior to TAB.

   c. 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.

5. Assist and cooperate with the CxA in the following manner:

   a. Using a skilled technician who is familiar with this building, execute the functional testing of the controls system as specified for the controls contractor in the Commissioning Plan. Provide two-way radios during the testing.

   b. Execute all control system trend logs specified requested by the CxA.

6. The 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 in Division 01 Section "General Commissioning Requirements". At minimum, the plan shall include for each type of equipment controlled by the automatic controls:

   a. System name.

   b. List of devices.

   c. Step-by-step procedures for testing each controller after installation, including:

      1) Process of verifying proper hardware and wiring installation.

      2) Process of downloading programs to local controllers and verifying that they are addressed correctly.

      3) Process of performing operational checks of each controlled component.

      4) Plan and process for calibrating valve and damper actuators and all sensors.
5) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.

d. 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.

e. A description of the instrumentation required for testing.

f. Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CxA and TAB contractor for this determination.

7. Provide a signed and dated certification to the CxA and CM 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.

8. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as specified in Section 230900.

9. 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).

D. TAB Contractor. The duties of the TAB contractor, in addition to those listed in 230593 are:

1. Six weeks prior to starting TAB, submit to the CM the qualifications of the site technician for the project, including the name of the contractors and facility managers of recent projects the technician on which was lead. The Owner will approve the site technician’s qualifications for this project.

2. Submit the outline of the TAB plan and approach for each system and component to the Owner, CxA, CM and the controls contractor six weeks prior to starting the TAB. This plan will be developed after the TAB has some familiarity with the control system.

3. The submitted plan will include:

   a. Certification that the TAB contractor has reviewed the construction documents and the systems with the design engineers and contractors to sufficiently understand the design intent for each system.

   b. An explanation of the intended use of the building control system. The controls contractor will comment on feasibility of the plan.

   c. 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.

   d. Discussion of what notations and markings will be made on the duct and piping drawings during the process.

   e. Final test report forms to be used.

   f. Detailed step-by-step procedures for TAB work for each system and issue: terminal flow calibration (for each terminal type), diffuser proportioning, branch / submain proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions, etc. Criteria for using air flow straighteners or relocating flow stations and sensors will be discussed. Provide the analogous explanations for the water side.
g. List of all air flow, water flow, sound level, system capacity and efficiency measurements to be performed and a description of specific test procedures, parameters, formulas to be used.

h. Details of how total flow will be determined (Air: sum of terminal flows via BAS calibrated readings or via hood readings of all terminals, supply (SA) and return air (RA) pitot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic, etc.).

i. The identification and types of measurement instruments to be used and their most recent calibration date.

j. Specific procedures that will ensure that both air and water side are operating at the lowest possible pressures and provide methods to verify this.

k. Confirmation that TAB understands the outside air ventilation criteria under all conditions.

l. Details of whether and how minimum outside air cfm will be verified and set, and for what level (total building, zone, etc.).

m. Details of how building static and exhaust fan / relief damper capacity will be checked.

n. Proposed selection points for sound measurements and sound measurement methods.

o. Details of methods for making any specified coil or other system plant capacity measurements.

p. Details of any TAB work to be done in phases (by floor, etc.), or of areas to be built out later.

q. Details regarding specified deferred or seasonal TAB work.

r. Details of any specified false loading of systems to complete TAB work.

s. Details of all exhaust fan balancing and capacity verifications, including any required room pressure differentials.

t. Details of any required interstitial cavity differential pressure measurements and calculations.

u. Plan for hand-written field technician logs of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests (scope and frequency).

v. Plan for formal progress reports (scope and frequency).

w. Plan for formal deficiency reports (scope, frequency and distribution).

4. A running log of events and issues shall be kept by the TAB field technicians. Submit hand-written reports of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests to the Owner, CxA and CM at least twice a week.

5. Communicate in writing to the controls contractor all set point and parameter changes made or problems and discrepancies identified during TAB which affect the control system setup and operation.

6. Provide a draft TAB report within two weeks of completion. A copy will be provided to the CxA. The report will contain a full explanation of the methodology, assumptions and the results in a clear format with designations of all uncommon abbreviations and column headings. The report should follow the latest and most rigorous reporting recommendations by AABC, NEBB or ASHRAE Standard 111 (as specified).

7. Provide the CxA with any requested data, gathered, but not shown on the draft reports.

8. Provide a final TAB report for the CxA with details, as in the draft.
9. Conduct functional performance tests and checks on the original TAB as specified for TAB in the Commissioning Plan.

E. CxA'S RESPONSIBILITIES
1. Provide review comments on the 100% DDs and 100% CDs related to the BE for compliance with the design intent and Owner’s Project requirements. The CxA shall review the design; identify design issues and/or conflicts that would present a problem for the total system commissioning.
2. Provide comments on submittals related to the HVAC systems. Provide written comments to A/E for their consideration in their review of the submittals.
3. Include CxA responsibilities in this article that have an impact on Contractor's activities and responsibilities.
4. Provide Project-specific construction pre-functional checklists and commissioning process functional test procedures for actual HVAC&R systems, assemblies, equipment, and components to be furnished and installed as part of the construction contract.
5. Direct commissioning testing.
6. Verify testing, adjusting, and balancing of Work are complete.

1.6 COMMISSIONING DOCUMENTATION
A. Provide the following information to the CxA for inclusion in the commissioning plan:
1. Plan for delivery and review of submittals, systems manuals, and other documents and reports.
2. Identification of installed systems, assemblies, equipment, and components including design changes that occurred during the construction phase.
3. Process and schedule for completing construction pre-functional checklists and manufacturer's prestart and startup checklists for HVAC&R systems, assemblies, equipment, and components to be verified and tested.
4. Certificate of completion certifying that installation, prestart checks, and startup procedures have been completed.
5. Certificate of readiness certifying that HVAC&R systems, subsystems, equipment, and associated controls are ready for testing.
6. Test and inspection reports and certificates.
7. Corrective action documents.
8. Verification of testing, adjusting, and balancing reports.

1.7 SUBMITTALS
A. Certificates of readiness.
B. Certificates of completion of installation, prestart, and startup activities.
PART 3 - EXECUTION

3.1 GENERAL DOCUMENTATION REQUIREMENTS
   A. Refer to Division 01 Section “General Commissioning Requirements”

3.2 SYSTEMS TO BE COMMISSIONED
   A. Refer to Division 01 Section “General Commissioning Requirements”

3.3 TESTING PREPARATION
   A. Certify that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.
   B. Certify that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.
   C. Certify that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.
   D. Set systems, subsystems, and equipment into operating mode to be tested (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).
   E. Inspect and verify the position of each device and interlock identified on checklists.
   F. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.
   G. Testing Instrumentation: Install measuring instruments and logging devices to record test data as directed by the CxA.

3.4 TESTING AND BALANCING VERIFICATION
   A. Prior to performance of testing and balancing Work, provide copies of reports, sample forms, checklists, and certificates to the CxA.
   B. Notify the CxA at least 15 days in advance of testing and balancing Work, and provide access for the CxA to witness testing and balancing Work.
   C. Provide technicians, instrumentation, and tools to verify testing and balancing of HVAC&R systems at the direction of the CxA.
1. The CxA will notify testing and balancing Contractor 15 days in advance of the date of field verification. Notice will not include data points to be verified.
2. The testing and balancing Contractor shall use the same instruments (by model and serial number) that were used when original data were collected.
3. Failure of an item includes, other than sound, a deviation of more than 10 percent. Failure of more than 10 percent of selected items shall result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a deviation of 3 dB shall result in rejection of final testing. Variations in background noise must be considered.
4. Remedy the deficiency and notify the CxA so verification of failed portions can be performed.

3.5 GENERAL TESTING REQUIREMENTS

A. Provide technicians, instrumentation, and tools to perform commissioning test at the direction of the CxA.

B. Scope of HVAC&R testing shall include entire HVAC&R installation, from central equipment for heat generation and refrigeration through distribution systems to each conditioned space. Testing shall include measuring capacities and effectiveness of operational and control functions.

C. Test all operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.

D. The CxA along with the HVAC&R Contractor, testing and balancing Contractor, and HVAC&R Instrumentation and Control Contractor shall prepare detailed testing plans, procedures, and checklists for HVAC&R systems, subsystems, and equipment.

E. Tests will be performed using design conditions whenever possible.

F. Simulated conditions may need to be imposed using an artificial load when it is not practical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by the CxA and document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions.

G. The CxA may direct that set points be altered when simulating conditions is not practical.

H. The CxA may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are not practical.

I. If tests cannot be completed because of a deficiency outside the scope of the HVAC&R system, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests.

J. If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.
3.6 HVAC&R SYSTEMS, SUBSYSTEMS, AND EQUIPMENT TESTING PROCEDURES

A. Boiler Testing and Acceptance Procedures: Testing requirements are specified in Division 23 boiler Sections. Provide submittals, test data, inspector record, and boiler certification to the CxA.

B. HVAC&R Instrumentation and Control System Testing: Field testing plans and testing requirements are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls." Assist the CxA with preparation of testing plans.

C. Building Automation System (BAS) Controls Start-up and Commissioning
1. When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. All testing, calibrating, adjusting and final field adjustments shall be completed by the installer. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power.
2. Provide any recommendation for system modification in writing to Owner. Do not make any system modification, including operating parameters and control settings, without prior approval of Owner.
3. The BASC contractor shall submit to the Architect/Engineer a detailed Dynamic Mode Test procedure and schedule, in writing, thirty (30) days prior to the period for the initial dynamic mode testing. During this time frame the Architect/Engineer will prepare a detailed punch list of the BAS installation.
4. The BASC shall provide a complete BAS database on CD upon completion of the dynamic mode and endurance testing.
5. General Dynamic Mode Testing Requirements
   a. Test a complete subsystem(s), one at a time, in a dynamic mode of operation simulating as many modes of operation as possible during the testing time period.
   b. The Dynamic Mode Testing shall be organized to demonstrate to the operating staff and the Architect/Engineer the proper sequence of operation for all systems. All mechanical and electrical systems served by the BAS shall be substantially complete and accepted by the Owner prior to Dynamic Mode Testing.
   c. Submit a schedule of events indicating dates, times, length of demonstration, required participants by sub-system, (30) days, prior to the first test.
   d. A punch list will be generated as part of the Dynamic Mode Testing. This punch list (prepared by the Operating Staff and Architect/Engineer) will form the basis for BAS substantial completion.
   e. Dynamic Mode Testing Requirements
      1) Coordinate the testing procedures of this division with the associated systems of Division 23 and Division 26 so that the total electro-mechanical and BAS work can be observed.
      2) Submit Installation Inspection Reports for all Control Units and Intelligent Devices indicating proper installation.
      3) In conjunction with the work of other Divisions, thoroughly test all equipment and systems in a dynamic mode simulating all operating sequences including safety shutdown and emergency fire mode.
      4) Initiate Endurance Testing Trend Logs for all systems in the time-frame and manner specified in this Section.
      5) Demonstrate User Interface software graphics and penetration menus for the User Interface workstation and supervisory control unit.
6. Endurance Testing
   a. Concurrent with the Dynamic Mode Testing initiate trend logs for each sub-system to be tested. The logs should monitor, in 15 minute intervals, all major I/O including control loops, alarms, discrete I/O status.
   b. The trend logs shall be executed for a (2) week period for each sub-system. Submit the trend logs for review of the Operating Staff and the Architect/Engineer. Graphed summary results are encouraged to aid in the acceptance review process.

7. Upon receipt of the detailed punch list from the Architect/Engineer, prepare an Installation Inspection Report showing, by system, each outstanding item on the punch list and those items compiled by the contractor as outlined in Article 3.4.G. After all items appearing on the Installation Inspection Report are completed, make a second written punch list to the Architect/Engineer.

8. Installation Inspection Report
   a. The Contractor shall verify prior to the Endurance Testing and Dynamic Mode Testing that all Control Units, Intelligent Devices, routers, gateways, etc. are ready for operation. This inspection shall verify that the following items have been properly installed.
      1) Network connection.
      2) Power connection.
      3) Proper power supply voltage and type.
      4) Electrical installation conforms to local code authorities.
      5) Valves: (Normally open or closed).
      6) Fail safe devices are equipped with spring return operators.
      7) Device or control unit in a stand-alone mode accomplishes the following:
         a) Operate smoothly throughout entire control range without binding or cogging.
         b) Sensors have been calibrated to specifications.
         c) Differential pressure transmitters have been zero and span adjusted.
         d) With application code loaded, executes specific control loops effectively without hunting or hysteresis
   8) Point to point check of all digital I/O for continuity and correct execution of the functional operation.
   9) Submit an Inspection Log prior to the Dynamic Mode Testing which enumerates the above in a check list form for all Control Units and Intelligent Devices. Indicate corrective action employed to deal with non-conforming or defective products and/or product installations.

9. Owner Acceptance: Upon the successful completion of the Dynamic Mode test, the BAS shall be considered acceptable to the Owner. At this time, the Controls Contractor shall issue a letter to the Architect/Engineer signifying Owner acceptance of installation of the BAS, and that the BAS is substantial complete. The date of the letter will signify the start of the system warranty period.

10. Pipe system cleaning, flushing, hydrostatic tests, and chemical treatment requirements are specified in Division 23 piping Sections. HVAC&R Contractor shall prepare a pipe system cleaning, flushing, and hydrostatic testing plan. Provide cleaning, flushing, testing, and treating plan and final reports to the CxA. Plan shall include the following:
    a. Sequence of testing and testing procedures for each section of pipe to be tested, identified by pipe zone or sector identification marker. Markers shall be keyed to Drawings for each pipe sector, showing the physical location of each designated pipe test section. Drawings keyed to pipe zones or sectors shall be formatted to allow each section of piping to be physically located and identified when referred
to in pipe system cleaning, flushing, hydrostatic testing, and chemical treatment plan.
b. Description of equipment for flushing operations.
c. Minimum flushing water velocity.
d. Tracking checklist for managing and ensuring that all pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

11. Energy Supply System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of hot-water systems and equipment at the direction of the CxA. The CxA shall determine the sequence of testing and testing procedures for each equipment item and pipe section to be tested.

12. Refrigeration System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of chillers, cooling towers, refrigerant compressors and condensers, heat pumps, and other refrigeration systems. The CxA shall determine the sequence of testing and testing procedures for each equipment item and pipe section to be tested.

13. HVAC&R Distribution System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of air, steam, and hydronic distribution systems; special exhaust; and other distribution systems, including HVAC&R terminal equipment and unitary equipment.


3.7 DEFICIENCIES/NON-CONFORMANCE, COST OF RETESTING, FAILURE DUE TO MANUFACTURER DEFECT

A. Refer to Division 01 Section “General Commissioning Requirements” for requirements pertaining to deficiencies/non-conformance, cost of retesting, or failure due to manufacturer defect.

3.8 APPROVAL

A. Refer to Division 01 Section “General Commissioning Requirements” for approval procedures.

3.9 DEFERRED TESTING / SEASONAL TESTING

A. Refer to Division 01 Section “General Commissioning Requirements” for requirements pertaining to deferred testing.

3.10 OPERATION AND MAINTENANCE MANUALS

A. The Operation and Maintenance Manuals shall conform to Contract Documents requirements as stated in Division 01.

B. Refer to Division 01 Section “General Commissioning Requirements” for the AE and CxA roles in the Operation and Maintenance Manual contribution, review and approval process.
C. The following O&M manual requirements do not replace O&M manual documentation requirements elsewhere in these specifications.

D. Division 23 shall compile and prepare documentation for all equipment and systems covered in Division 23 and deliver this documentation to the CM for inclusion in the O&M manuals, according to this section and Section 017823, prior to the training of owner personnel.

E. The CxA shall receive a copy of the O&M manuals for review.

F. Special Control System O&M Manual Requirements. In addition to documentation that may be specified elsewhere, the controls contractor shall compile and organize at minimum the following data on the control system in labeled 3-ring binders with indexed tabs.

1. Three 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.
   b. Full as-built set of control drawings (refer to Submittal section above for details).
   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 submittals (Part 1 of this section), a listing of all rooms shall be provided with the following information for each room:
      1) Floor
      2) Room number
      3) Room name
      4) Air handler unit ID
      5) Reference drawing number
      6) Air terminal unit tag ID
      7) Heating and/or cooling valve tag ID
      8) Minimum cfm
      9) Maximum cfm
   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.
   g. Electronic copy on disk of the entire program for this facility.
   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. The 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 CxA for inclusion in the Commissioning Record Book.

G. Special TAB Documentation Requirements. The TAB will compile and submit the following with other documentation that may be specified elsewhere in the Specifications.

   1. Final report containing an explanation of the methodology, assumptions, test conditions and the results in a clear format with designations of all uncommon abbreviations and column headings.
   2. The TAB shall mark on the drawings where all traverse and other critical measurements were taken and cross reference the location in the TAB report.

H. Review and Approvals. Review of the commissioning related sections of the O&M manuals shall be made by the A/E and by the CxA. Refer to Section 019113 for details.

3.11 SYSTEMS MANUAL REQUIREMENTS

A. The Systems Manual is intended to be a usable information resource containing all of the information related to the systems, assemblies, and Commissioning Process in one place with indexes and cross references. The CM shall include final approved versions of the following information for the Systems Manual:

   1. As-Built System Schematics
   2. Verified Record Drawings
   3. Test Results (not otherwise included in Cx Record)
   4. Periodic Maintenance Information for computer maintenance management system
   5. Recommendations for recalibration frequency of sensors and actuators
   6. A list of contractors, subcontractors, suppliers, architects, and engineers involved in the project along with their contact information
   7. Training Records, Information on training provided, attendees list, and any on-going training

B. This information shall be organized and arranged by building system, such as fire alarm, chilled water, heating hot water, etc.
C. Information should be provided in an electronic version to the extent possible. Legible, scanned images are acceptable for non-electronic documentation to facilitate this deliverable.

3.12 TRAINING OF OWNER PERSONNEL

A. The CM shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Refer to Section 019113 for additional details.

B. The CxA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 019113 for additional details.

C. Mechanical Contractor. The mechanical contractor shall have the following training responsibilities:

1. Provide the CxA with a training plan two weeks before the planned training according to the outline described in Section 019113, Part 3.09.
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, all HVAC equipment (ex. pumps, heat exchangers, chillers, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, 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 is required. More than one party may be required to execute the training.
6. The 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. The 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 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, shut-down, 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 1-1996, is recommended.

i. Classroom sessions shall include the use of overhead projections, slides, video/audio-taped material as might be appropriate.

9. Hands-on training shall include start-up, operation in all modes possible, including manual, shut-down and any emergency procedures and preventative maintenance for all pieces of equipment.

10. The 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. Training shall occur after functional testing is complete, unless approved otherwise by the Owner.

D. Controls Contractor. The controls contractor shall have the following training responsibilities:

1. Provide the CxA and AE with a training plan four weeks before the planned training according to the outline described in Section 019113.

2. The 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. The standard operating manual for the system and any special training manuals will 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. Manuals will be approved by the CxA and AE. Copies of audiovisuals shall be delivered to the Owner.

4. The trainings will be tailored to the needs and skill-level of the trainees.

5. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. 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. The 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 8 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 set points 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.

7) Setting up and changing an air terminal unit controller.

8) Graphics generation

9) Point database entry and modifications

10) Understanding DDC field panel operating programming (when applicable)

c. Training III. 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 - The TAB contractor shall have the following training responsibilities:

1. TAB shall meet for 4 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.
3.13 WRITTEN WORK PRODUCTS

A. Written work products of Contractors will consist of the start-up and initial checkout plan described in Section 019113 and the filled out start-up, initial checkout and prefunctional checklists.

END OF SECTION 230800