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*Title: General Commissioning Requirements
Section 01 91 00*

SECTION 01 91 00 – GENERAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this Section.
- B. Section 22 08 00 – Commissioning of Plumbing
- C. Section 23 08 00 – Commissioning of HVAC
- D. Section 26 08 00 – Commissioning of Electrical Systems

1.2 SUMMARY

- A. This section includes:
 - 1. **Commissioning:** Commissioning is a systematic process of ensuring that all building systems perform interactively according to the design intent and the Owner's operational needs. This is achieved by beginning in the design phase and documenting design intent and continuing through construction, acceptance, and the warranty period with actual verification of performance. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment startup, control system calibration, testing and balancing, performance testing and training.
 - 2. Commissioning during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:
 - a. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing contractors.
 - b. Verify and document proper performance of equipment and systems.
 - c. Verify that O&M documentation left on site is complete.
 - d. Verify that the Owner's operating personnel are adequately trained.

This section addresses those commissioning activities that involve the Contractor and are completed during and after the construction phase. The commissioning process should also involve activities that are beyond the scope of this specification document.

This specification includes requirements that should be sufficient to meet the LEED-NC and LEED-EB commissioning prerequisites. The LEED-NC credit 3 for “Enhanced Commissioning” includes additional requirements, notably design-phase commissioning, that exceed the scope of this specification.

3. The commissioning process does not take away from or reduce the responsibility of the Contractor to meet the Contract Documents.

B. Related Sections include the following:

1. Contract drawings and specifications, general provisions of the contract, including general and supplementary conditions, architectural, electrical, and mechanical provisions, and Division 1 Specification Sections apply to work of this Section.

1.3 ABBREVIATIONS

- A. Abbreviations: The following are common abbreviations used in this *Specification* and in the *Commissioning Plan*.**

A/E	Architect and design engineers	GC	General Contractor
CA	Commissioning authority	IC	Installing Contractor
CC	Construction checklist	MC	Mechanical Contractor
CT	Commissioning Team	RTF	Resolution Tracking Form
Cx	Commissioning	Subs	Subs to Prime Contractors
Cx Plan	Commissioning Plan document	TAB	Test and balance Contractor (If independent)
EC	Electrical Contractor	TCC	Temperature Controls Contractor
FT	Functional performance test		

1.4 COORDINATION

- A. Commissioning Team** The members of the commissioning team consist of the CA, the GC, the Architect and Design Engineers (particularly the Mechanical Engineer), the MC, the EC, the TAB representative, the TCC, and any other installing subs or suppliers of equipment. If known, the Owner’s building or plant operator/engineer is also a member of the commissioning team.
- B. Management:** The CA directs and coordinates the commissioning activities and reports to the Owner. All members work together to fulfill their contracted responsibilities and meet the objectives of

the Contract Documents. The CA's responsibilities are the same regardless of who hired the CA.

- C. **Scheduling:** The CA will work with the GC according to established protocols to schedule the commissioning activities. The CA will provide sufficient notice (generally two weeks' notice) to the GC for scheduling commissioning activities. The GC will integrate all commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process.
- D. The CA will provide the initial schedule of primary commissioning events, or commissioning milestones, at the initial commissioning meeting. The Commissioning Plan provides a format for this schedule. As construction progresses and more detailed schedules are available from the GC, the CA will adjust the commissioning schedule accordingly.

1.5 COMMISSIONING PROCESS

- A. **Commissioning Plan:** The Commissioning Plan, provided as part of the bid documents, is binding on the Contractor. The commissioning plan provides guidance in the execution of the commissioning process. The Specifications will take precedence over the Commissioning Plan.
- B. **Commissioning Process:** The following narrative provides a brief overview of the typical commissioning tasks during construction and the general order in which they occur.
 - 1. Commissioning during construction begins with an initial Commissioning meeting conducted by the CA where the commissioning process is reviewed with the commissioning team members.
 - 2. Additional meetings will be required throughout construction, scheduled by the CA with necessary parties attending, to plan, coordinate, schedule future activities and resolve problems.
 - 3. Equipment documentation is distributed by the A/E to the CA during the normal submittal process, including detailed start-up procedures.
 - 4. The CA works with the Contractor in each discipline in developing startup plans and startup documentation formats, including providing the Contractor with construction checklists to be completed during the installation and startup process.
 - 5. In general, the checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels with

construction checklists being completed before functional testing occurs.

6. The Contractors, under their own direction, will execute and document the completion of construction checklists and perform startup and initial checkout. The CA documents that the checklists and startup were completed according to the approved plans. This may include the CA witnessing start-up of selected equipment.
7. The CA develops specific equipment and system functional performance test procedures.
8. The functional test procedures are reviewed with the A/E, CA, and Contractors.
9. The functional testing and procedures are executed by the Contractors under the direction of, and documented by, the CA.
10. During initial functional tests and for critical equipment, the Engineer will witness the testing.
11. Items of non-compliance in material, installation, or setup are corrected at the Contractor's expense, and the system is retested.
12. The CA reviews the O&M documentation for completeness.
13. The project will not be considered substantially complete until the conclusion of Commissioning functional testing procedures as defined in the Commissioning Plan.
14. The CA reviews and coordinates the training provided by the Contractors and verifies that it was completed.
15. Deferred testing is conducted as specified or required.

1.6 RESPONSIBILITIES

- A. The responsibilities of various parties in the commissioning process are provided in this section. The responsibilities of the MC, TAB and TCC are in Divisions 22 and 23, those of the EC in Division 26, and those of the GC related to the building envelope and LEED-related credits and prerequisites in Division 1. It is noted that the services for the A/E and CA are not provided for in this Contract. That is, the Contractor is not responsible for providing their services. Their responsibilities are listed in the Commissioning Plan.
- B. All Parties:

1. Follow the Commissioning Plan.
 2. Attend an initial commissioning meeting and additional meetings, as necessary.
- C. General Contractor (GC)**
1. Construction and Acceptance Phase:
 - a. Facilitate the coordination of the commissioning work by the CA, and with the GC and CA, ensure that commissioning activities are being scheduled into the master schedule.
 - b. Include the cost of commissioning in the total contract price.
 - c. Furnish a copy of all construction documents, addenda, change orders, and approved submittals and shop drawings related to commissioned equipment to the CA.
 - d. In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks, and training.
 - e. Ensure that all Contractors execute their commissioning responsibilities according to the Contract Documents and schedule.
 - f. A representative shall attend the initial commissioning meeting and other necessary meetings scheduled by the CA to facilitate the Cx process.
 - g. Coordinate and schedule the training of owner personnel.
 - 1) Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
 - h. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner to keep warranties in force.
 - i. Assist in equipment testing per agreements with sub-contractors.
 - j. Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these Contract Documents in the base bid price to the Contractor, except for stand-alone data logging equipment that may be used by the CA.

- k. Through the Contractors they supply products to, analyze specified products and verify that the Designer has specified the newest most updated equipment reasonable for this project's scope and budget.
 - l. Provide information requested by CA regarding equipment sequence of operation and testing procedures.
 - 1) Review test procedures for equipment installed by factory representatives.
2. Warranty Period:
- a. Ensure that Subcontractors execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
- D. Ensure that Subcontractors correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

1.7 DEFINITIONS

- A. Acceptance Phase: Phase of construction after startup and initial checkout when functional performance tests, O&M documentation review, and training occur
- B. Approval: Acceptance that a piece of equipment or system has been properly installed and is functioning in the tested modes according to the Contract Documents
- C. Architect / Engineer (A/E): The prime consultants who comprise the design team, generally the HVAC mechanical designer/engineer and the electrical designer/engineer
- D. Owner's Project Requirements: The Owner's Project Requirements is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The Owner's Project Requirements describes the systems, components, conditions, and methods chosen to meet the intent. Some reiterating of the design intent may be included.
- E. Commissioning Authority (CA): An independent authority, not otherwise associated with the A/E team members or the Contractor, though he/she may be hired as a subcontractor to them. The CA directs and coordinates the day-to-day commissioning activities. The CA does not take an oversight role.

This definition meets LEED EA prerequisite 1, but is slightly less stringent than LEED EA Credit 3, which requires that the individual serving as the Commissioning Authority is neither an employee of,

nor contracted through, a Contractor or Construction Manager holding construction contracts.

- F. Commissioning Plan: An overall plan, developed before or after bidding that provides the structure, schedule, and coordination planning for the commissioning process**
- G. Construction Checklist (CC): A list of items to inspect and elementary component tests to conduct to verify proper installation of equipment, provided by the CA to the Sub. Construction checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension correct, oil levels OK, labels affixed, gages in place, sensors calibrated, etc.). However, some construction checklist items entail simple testing of the function of a component, a piece of equipment, or system (such as measuring the voltage imbalance on a three phase pump motor of a chiller system). The word construction refers to before functional testing. Construction checklists augment and are combined with the manufacturer's start-up checklist. Even without a commissioning process, Contractors typically perform some, if not many, of the construction checklist items a commissioning authority will recommend. However, few Contractors document in writing the execution of these checklist items. Therefore, for most equipment, the Contractors execute the checklists on their own. The Commissioning Authority only requires that the procedures be documented in writing and does not witness much of the completion of construction checklists, except for larger or more critical pieces of equipment.**
- H. Contract Documents: The documents binding on parties involved in the construction of this Project (drawings, specifications, change orders, amendments, contracts, Cx Plan, etc.)**
- I. Contractor: The general contractor or authorized representative**
 - 1. Control system: The central building energy management control system**
- J. Data Logging: Monitoring flows, currents, status, pressures, etc. of equipment using stand-alone data loggers separate from the control system**
- K. Deferred Functional Tests: FTs that are performed later, after substantial completion, due to partial occupancy, equipment, seasonal requirements, design, or other site conditions that prevent the test from being performed**
- L. Deficiency: A condition in the installation or function of a component, piece of equipment or system that is not in compliance with the Contract Documents**

- M. Design Intent: A dynamic document that provides the explanation of the ideas, concepts, and criteria that are considered to be very important to the owner. It is initially the outcome of the programming and conceptual design phases.**
- N. Factory Testing: Testing of equipment on-site or at the factory by factory personnel with a Project Manager present**
- O. Functional Performance Test (FT): Test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Functional testing is the dynamic testing of systems (rather than just components) under full operation (e.g., the chiller pump is tested interactively with the chiller functions to see if the pump ramps up and down to maintain the differential pressure setpoint). Systems are tested under various modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, etc. The systems are run through all the control system's sequences of operation, and components are verified to be responding as the sequences state. Traditional air or water test and balancing (TAB) is not functional testing, in the commissioning sense of the word. TAB's primary work is setting up the system flows and pressures as specified, while functional testing is verifying that which has already been set up. The Commissioning Authority develops the functional test procedures in a sequential written form, coordinates, oversees, and documents the actual testing, which is usually performed by the installing Contractor or vendor. FTs are performed after construction checklists and startup are complete.**
- P. General Contractor (GC): The Contractor for this project. Generally refers to all the GC's subs as well. Also referred to as the Contractor, in some contexts.**
- Q. Indirect Indicators: Indicators of a response or condition, such as a reading from a control system screen reporting a damper to be 100% closed**
- R. Installing Contractor: Contractor who installs specific equipment and/or systems**
- S. Manual Test: Using hand-held instruments, immediate control system readouts, or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the "observation")**
- T. Monitoring: The recording of parameters (flow, current, status, pressure, etc.) of equipment operation using data loggers or the trending capabilities of control systems**
- U. Non-Compliance: See Deficiency**
- V. Non-Conformance: See Deficiency**

- W. Over-written Value: Writing over a sensor value in the control system to see the response of a system (e.g., changing the outside air temperature value from 50°F to 75°F to verify economizer operation). See also “Simulated Signal.”**
- X. Owner-Contracted Tests: Tests paid for by the Owner outside the GC’s contract and for which the CA does not oversee. These tests will not be repeated during functional tests if properly documented.**
- Y. Phased Commissioning: Commissioning that is completed in phases (by floors, for example) due to the size of the structure or other scheduling issues, in order minimize the total construction time**
- Z. Sampling: Functionally testing only a fraction of the total number of identical or near-identical pieces of equipment. Refer to Part 3.4 F for details.**
- AA. Seasonal Performance Tests: FTs that are deferred until the system(s) will experience conditions closer to their design conditions**
- BB. Simulated Condition: Condition that is created for the purpose of testing the response of a system (e.g., applying a hair blower to a space sensor to see the response in a VAV box)**
- CC. Simulated Signal: Disconnecting a sensor and using a signal generator to send an amperage, resistance, or pressure to the transducer and DDC system to simulate a sensor value**
- DD. Specifications: The construction specifications of the Contract Documents**
- EE. Startup: The initial starting or activating of dynamic equipment, including executing construction checklists**
- FF. Subs: The subcontractors to the Prime Contractor who provide and install building components and systems**
- GG. Test Procedures: The step-by-step process that must be executed to fulfill the test requirements. The CA develops the test procedures.**
- HH. Test Requirements: Requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures. The test requirements for each system are specified in the respective section of the Contract Documents.**
- II. Trending: Monitoring using the building control system**
- JJ. Vendor: Supplier of equipment**

KK. Warranty Period: Warranty period for entire project, including equipment components. Warranty begins at Substantial Completion and extends for at least one year, unless specifically noted otherwise in the Contract Documents and accepted submittals.

1.8 SYSTEMS TO BE COMMISSIONED

A. The following checked systems are to be commissioned.

- | | |
|--|--|
| <input type="checkbox"/> <u>HVAC Equipment and System</u> | <input type="checkbox"/> <u>Electrical Equipment and System</u> |
| <input type="checkbox"/> Variable Speed Drives | <input type="checkbox"/> Power Distribution System |
| <input type="checkbox"/> Hydronic Piping systems | <input type="checkbox"/> Lighting Control Systems |
| <input type="checkbox"/> HVAC Pumps | <input type="checkbox"/> Lighting Control Programs |
| <input type="checkbox"/> Boilers | <input type="checkbox"/> Engine Generators |
| <input type="checkbox"/> Chemical Treatment System | <input type="checkbox"/> Transfer Switches |
| <input type="checkbox"/> Air Cooled Condensing Units | <input type="checkbox"/> Switchboard |
| <input type="checkbox"/> Makeup Air Systems | <input type="checkbox"/> Panelboards |
| <input type="checkbox"/> Air Handling Units | <input type="checkbox"/> Grounding |
| <input type="checkbox"/> Underfloor Air Distribution | <input type="checkbox"/> Fire Alarm and Interface Items with HVAC |
| <input type="checkbox"/> Centrifugal Fans | <input type="checkbox"/> Security System |
| <input type="checkbox"/> Ductwork | |
| <input type="checkbox"/> Fire/Smoke Dampers | |
| <input type="checkbox"/> Automatic Temperature Controls – Including an intentional sequence of operation | <input type="checkbox"/> <u>Plumbing System</u> |
| <input type="checkbox"/> Laboratory Fume Hoods | <input type="checkbox"/> Domestic Water Heater |
| <input type="checkbox"/> Testing, Adjusting, and Balancing | <input type="checkbox"/> Air Compressor & Dryer |
| <input type="checkbox"/> Building / Space Pressurization | <input type="checkbox"/> Storm Water Oil / Grit Separators |
| <input type="checkbox"/> Ceiling Radiant Heating | |
| <input type="checkbox"/> Underfloor Radiant Heating | <input type="checkbox"/> <u>Building Envelope</u> |
| | <input type="checkbox"/> Building Insulation Installation |
| | <input type="checkbox"/> Building Roof Installation Methods |
| | <input type="checkbox"/> Doors & Windows Installation Methods |
| | <input type="checkbox"/> Water Infiltration / Shell Drainage Plain |

Commissioning needs may differ by project; however, commissioning the building envelope systems, domestic water heating, power distribution, ductwork, and any hydronic piping systems is strongly recommended for any project.

To meet the LEED EA prerequisite 1 or the LEED-NC credit 3, commissioning must be completed, at a minimum, for: 1. HVAC&R systems; 2. Lighting and daylighting controls; 3. Domestic hot water systems; 4. Renewable energy systems. Commissioning of water-using systems, building envelope systems, and others is recommended but not required.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

- A. All standard testing equipment required to perform startup and initial checkout and required functional performance testing shall be provided by the ICI for the equipment being tested. For example, the MC of Division 23 shall ultimately be responsible for all standard testing equipment for the HVAC system and controls system in Division 23, except for equipment specific to and used by TAB in their commissioning responsibilities. The Installing Contractor shall provide two-way radios.**
- B. Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents, shall be included in the base bid price to the Contractor and left on site, except for stand-alone data logging equipment that may be used by the CA.**
- C. Temporary Data logging equipment and software required to test equipment will be provided by the CA but shall not become the property of the Owner.**
- D. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the Specifications. If not otherwise noted, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration within the past year to an accuracy of 0.5°F and a resolution of + or - 0.1°F. Pressure sensors shall have an accuracy of + or - 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals and when dropped or damaged. Calibration tags shall be affixed or certificates readily available.**
- E. Refer to Part 3 for details regarding equipment that may be required to simulate required test conditions.**

PART 3 - EXECUTION

3.1 MEETINGS

- A. Commissioning Meeting: Within 60 days of commencement of construction, the CA will schedule, plan and conduct a commissioning meeting with the entire commissioning team in attendance. Meeting minutes will be distributed to all parties by the CA. Information gathered from this meeting will allow the CA to revise the Commissioning Plan, which will be distributed to all parties.**

- B. Miscellaneous Meetings: Other meetings will be planned and conducted by the CA as construction progresses. These meetings will cover coordination, deficiency resolution and planning issues with particular contractors. The CA will plan these meetings and will minimize unnecessary time being spent by contractors. For large projects, these meetings may be held monthly, until the final 3 months of construction when they may be held as frequently as one per week.**

3.2 STARTUP, CONSTRUCTION CHECKLISTS, AND INITIAL CHECKOUT

- A. The following procedures apply to all equipment to be commissioned. Some systems that are not comprised so much of actual dynamic machinery, e.g., electrical system power quality, may have very simplified CCs and startup.**
- B. General: Construction checklists are important to ensure that the equipment and systems are hooked up correctly and operational. Checklists also ensure that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full construction checkout. No sampling strategies are used. The construction testing for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.**
- C. Startup and Initial Checkout Plan: The CA will assist the commissioning team members responsible for startup of any equipment in developing detailed startup plans for all equipment. The primary role of the CA in this process is to ensure that there is written documentation that each of the manufacturer-recommended procedures has been completed. Parties responsible for construction checklists and startup are identified in the initial commissioning meeting and in the checklist forms.**
 - 1. The CA adapts, if necessary, the representative construction checklists and procedures from the related sections. These checklists indicate required procedures to be executed as part of startup and initial checkout of the systems and the party responsible for their execution.**
 - 2. The CA provides these checklists and tests to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.**
 - 3. The Contractor responsible for the purchase of the equipment develops the full startup plan by combining (or adding to) the CA's checklists with the manufacturer's detailed startup and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include checklists**

and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.

- a. The full startup plan could consist of something as simple as:
 - 1) The CA's construction checklists
 - 2) The manufacturer's standard written startup procedures copied from the installation manuals with check boxes by each procedure and a signature block added by hand at the end
 - 3) The manufacturer's normally used field checkout sheets
4. The contractor submits the full startup plan to the CA for review and approval.
5. The CA reviews and approves the procedures and the format for documenting them, noting any procedures that need to be added.

D. Sensor and Actuator Calibration

1. All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages, and all actuators (dampers and valves) on all equipment shall be calibrated using the methods described below. Alternate methods may be used if approved by the CA beforehand. All test instruments shall have had a certified calibration within the last 12 months. Sensors installed in the unit at the factory with calibration certification provided need not be field-calibrated.
2. All procedures used shall be fully documented on the construction checklists or other approved forms, clearly referencing the procedures followed and written documentation of initial, intermediate, and final results.
3. **Sensor Calibration Methods**
 - a. **All Sensors:** Verify that all sensor locations are appropriate and away from causes of erratic operation. Verify that sensors with shielded cable are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading of each other for pressure. Tolerances for critical applications may be tighter.
 - b. **Sensors Without Transmitters--Standard Application:** Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, or building

automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.

- c. **Sensors With Transmitters--Standard Application:** Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until the ammeter reads 4 mA. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform to specified control ramps, reset schedules, proportional relationship, reset relationship, and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, or building automation system [BAS]) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- d. **Critical Applications:** For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

4. Tolerances, Standard Applications

5.

Sensor	Required Tolerance (+/-)	Sensor	Required Tolerance (+/-)
Cooling coil, chilled and condenser water temps	0.4F	Flow rates, water Relative humidity	4% of design 4% of design
AHU wet bulb or dew point	2.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.5F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, duct air temps	0.4F	CO monitor	0.01 % pts
Watt-hour, voltage and amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

6. Valve and Damper Stroke Setup and Check

- a. **EMS Readout:** For all valve and damper actuator positions checked, verify the actual position against the BAS readout.
- b. **Set pumps or fans to normal operating mode.** Command valve or damper closed, visually verify that valve or damper is closed and adjust output zero signal as required. Command valve or damper open, verify position is full open and adjust output signal as required. Command valve or damper to a few intermediate positions. If actual valve or damper position doesn't reasonably correspond, replace actuator or add pilot position indicator (for pneumatics).
- c. **Closure for heating coil valves (NO):** Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. For pneumatics, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.
- d. **Closure for cooling coil valves (NC):** Set cooling setpoint 20°F above room temperature. Observe the valve close. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set cooling setpoint to 20°F below room temperature. Observe valve open. For pneumatics, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

E. Execution of Construction Checklists and Startup

1. **Four weeks prior to startup, the contractors and vendors schedule startup and checkout with the GC and CA. The performance of the construction checklists, startup and checkout are directed and executed by the contractor or vendor. When checking off construction checklists, signatures may be required of other contractors for verification of completion of their work.**
2. **The CA will, at their own discretion, observe, at minimum, the procedures for each piece of primary equipment unless there are multiple units. In no case will the number of units witnessed be less than four on any one building, nor less than 20% of the total number of identical or very similar units.**

3. For lower-level components of equipment, (e.g., VAV boxes, sensors, controllers), the CA shall observe a sampling of the construction and startup procedures. The sampling procedures are identified in the Commissioning Plan.
4. The contractors shall execute startup and provide the CA with a signed and dated copy of the completed startup and construction tests and checklists.
5. Only installing individuals who have direct knowledge that a line item task on the construction checklist was actually performed shall initial or check off that item.

F. Deficiencies, Non-Conformance and Approval in Checklists and Startup

1. The contractors shall clearly list any outstanding items of the initial startup and construction procedures that were not completed successfully, at the bottom of the procedures form or on an attached sheet. The procedures form and any outstanding deficiencies are provided to the CA within two days of test completion.
2. The CA reviews the report and submits either a non-compliance report or an approval form to the contractors. The CA shall work with the Prime contractors to correct and retest deficiencies or uncompleted items. The CA will involve the contractors and others as necessary. The installing contractors shall correct all areas that are deficient or incomplete in the checklists and tests in a timely manner, and shall notify the CA as soon as outstanding items have been corrected and resubmit an updated startup report and a Statement of Correction on the original non-compliance report. When satisfactorily completed, the CA recommends approval of the execution of the checklists and startup of each system to the A/E using a standard form.
3. Items left incomplete, which later cause deficiencies or delays during functional testing, may result in back charges to the responsible party.

3.3 PHASED COMMISSIONING

- A. The project will require startup and initial checkout to be executed in phases. This phasing will be planned and scheduled in a coordination meeting of the CA, MC, TAB, TCC and the GC. Results will be added to the master and commissioning schedule.

3.4 FUNCTIONAL PERFORMANCE TESTING

- A. This subsection applies to all commissioning functional testing for all divisions.**
- B. The general list of equipment to be commissioned is found in this Section. The specific equipment and modes to be tested for each system are found in the respective sections.**
- C. The parties responsible to execute each test are listed with each test in the respective sections.**
- D. Objectives and Scope: The objective of functional performance testing is to demonstrate that each system is operating according to the Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems.**
 - 1. In general, each system should be operated through all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested. Specific modes required in this project are given in Divisions 22, 23, and 26, and other parts of the specification.**
- E. Development of Test Procedures: Before test procedures are written, the CA shall obtain all requested documentation and a current list of change orders affecting equipment or systems, including an updated points list, program code, control sequences and parameters. Using the testing parameters and requirements in Divisions 22, 23, 26, and elsewhere, the CA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each contractor or vendor responsible to execute a test shall provide limited assistance to the CA in developing the procedures review (answering questions about equipment, operation, sequences, etc.). Prior to execution, the CA shall provide a copy of the test procedures to the contractors, who shall review the tests for feasibility, safety, equipment, and warranty protection.**
 - 1. The CA shall review Owner-contracted factory testing or required Owner acceptance tests which the CA is not responsible to oversee, including documentation format, and shall determine what further testing or format changes may be required to comply with the Specifications. Redundancy of testing shall be minimized.**

2. The purpose of any given specific test is to verify and document compliance with the stated criteria of acceptance given on the test form.
3. Representative test formats and examples (not designed for this facility) are found in the appendices to Divisions 22, 23, and 26. The test procedure forms developed by the CA shall include (but not be limited to) the following information:
 - a. System and equipment or component name(s)
 - b. Equipment location and ID number
 - c. Unique test ID number, and reference to unique construction checklist and start-up documentation ID numbers for the piece of equipment
 - d. Date
 - e. Project name
 - f. Participating parties
 - g. A copy of the specification section describing the test requirements
 - h. A copy of the specific sequence of operations or other specified parameters being verified
 - i. Formulas used in any calculations
 - j. Required pre-test field measurements
 - k. Instructions for setting up the test
 - l. Special cautions, alarm limits, etc.
 - m. Specific step-by-step procedures to execute the test, in a clear, sequential, and repeatable format
 - n. Acceptance criteria of proper performance with a Yes / No checkbox to allow for clearly marking whether or not proper performance of each part of the test was achieved
 - o. A section for comments
 - p. Signatures and date block for the CA

F. Test Methods

1. Functional performance testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the

performance and analyzing the results using the control system's trend log capabilities or by stand-alone data loggers. Division 23 Sections and other Sections specify which methods shall be used for each test. The CA may substitute specified methods or require an additional method to be executed other than what was specified. The CA will determine which method is most appropriate for tests that do not have a method specified.

2. **Simulated Conditions:** Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
3. **Overwritten Values:** Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable, e.g., for the above case, by heating the outside air sensor with a hair dryer rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers, and devices shall have been calibrated.
4. **Simulated Signals:** Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.
5. **Altering Setpoints:** Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55°F, when the outside air temperature is above 55°F, temporarily change the lockout setpoint to be 2°F above the current outside air temperature.
6. **Indirect Indicators:** Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification is completed during construction testing.
7. **Setup:** Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The contractor executing the test shall

provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the contractor shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.

8. **Sampling: Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. Significant application differences and significant sequence of operation differences in otherwise identical equipment invalidates their common identity. A small size or capacity difference, alone, does not constitute a difference. The specific recommended sampling rates are specified with each type of equipment in Divisions 22, 23, and 26. It is noted that no sampling by contractors is allowed in construction checklist execution.**
 - a. **A common sampling strategy referenced in the Specifications as the “xx% Sampling—yy% Failure Rule” is defined by the following example.**
 - 1) **xx = the percent of the group of identical equipment to be included in each sample**
 - 2) **yy = the percent of the sample that if failing, will require another sample to be tested**
 - b. **The example below describes a 20% Sampling—10% Failure Rule.**
 - 1) **Randomly test at least 20% (xx) of each group of identical equipment. In no case test less than three units in each group. This 20%, or three, constitute the “first sample.”**
 - 2) **If 10% (yy) of the units in the first sample fail the functional performance tests, test another 20% of the group (the second sample).**
 - 3) **If 10% of the units in the second sample fail, test all remaining units in the whole group.**
 - 4) **If at any point, frequent failures are occurring and testing is becoming more troubleshooting than verification, the CA may stop the testing and require the contractor to perform and document a checkout of the remaining units, prior to continuing with functionally testing the remaining units.**
- G. **Coordination and Scheduling: The contractors shall provide sufficient notice to the CA regarding their completion schedule for the construction checklists and startup of all equipment and systems. The CA will schedule functional tests through the A/E, GC and other contractors. The CA shall direct, witness and document the functional testing of all equipment and systems. The contractors shall execute the tests.**
 1. **In general, functional testing is conducted after construction testing and startup has been satisfactorily completed. The**

control system is sufficiently tested and approved by the CA before it is used for TAB or to verify performance of other components or systems. The air balancing and water balancing is completed and debugged before functional testing of air-related or water-related equipment or systems. Testing proceeds from components to subsystems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is checked.

- H. **Problem Solving:** The CA will recommend solutions to problems found; however, the burden of responsibility to solve, correct, and retest problems is with the GC, contractors, and A/E.

The requirements of this section meet LEED-NC EA prerequisite 1 requirements for both System Performance Testing (or Functional Performance Testing) and Installation Inspections.

3.5 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

- A. **Documentation:** The CA shall witness and document the results of all functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the contractors for review. The CA will include the filled-out forms in the O&M manuals.
- B. **Non-Conformance**
1. The CA will record the results of the functional test on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the A/E on a standard non-compliance form.
 2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the CA. In such cases the deficiency and resolution will be documented on the procedure form.
 3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the CA will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so at the request of the Owner.
 4. As tests progress and a deficiency is identified, the CA discusses the issue with the executing contractor.
 - a. When there is no dispute on the deficiency and the contractor accepts responsibility to correct it:

- 1) The CA documents the deficiency and the Prime contractor's response and intentions, and they go on to another test or sequence. After the day's work, the CA submits the non-compliance reports to the A/E for signature, if required. A copy is provided to the contractor and CA. The contractor corrects the deficiency, signs the statement of correction at the bottom of the non-compliance form certifying that the equipment is ready to be retested, and sends it back to the CA.
 - 2) The contractor reschedules the test and coordinates with CA to establish a time and date that the test is to be repeated.
- b. If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible:
- 1) The deficiency shall be documented on the non-compliance form with the contractor's response and a copy given to the A/E and to the contractor representative assumed to be responsible.
 - 2) Resolutions are made at the lowest management level possible. Other parties are brought into the discussions as needed. Final interpretive authority is with the A/E. Final acceptance authority is with the A/E.
 - 3) The CA documents the resolution process.
 - 4) Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the statement of correction on the non-compliance form and provides it to the CA. The contractor reschedules the test and notifies the CA of the date and time the test is to be repeated. This will occur until satisfactory performance is achieved.
5. Cost of Retesting
- a. The cost for the contractor to retest a construction or functional test, if they are responsible for the deficiency, shall be theirs. If they are not responsible, any cost recovery for retesting costs shall be negotiated with the responsible parties.
 - b. For a deficiency identified, not related to any construction checklist or startup fault, the following shall apply: The CA will direct the retesting of the equipment once at no "charge" to the contractor for their time. However, the CA's time for a second retest will be charged to the contractor, who may choose to recover costs from the responsible Sub.
 - c. The time for the CA to direct any retesting required because a specific construction checklist or start-up test item, reported to have been successfully completed, but determined during functional testing to be faulty, will be back charged to the contractor, who may choose to

recover costs from the party responsible for executing the faulty construction test.

- d. Refer to the sampling section of Section 01810, for requirements for testing and retesting identical equipment.
6. The contractor shall respond in writing to the CA at least as often as commissioning meetings are being scheduled concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.
 7. The CA retains the original non-conformance forms until the end of the project.
 8. Any required retesting by any contractor shall not be considered a justified reason for a claim of delay or for a time extension by the contractor.
- C. Failure Due to Manufacturer Defect: If 10%, or three, whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively) due to manufacturing defect, not allowing it to meet its submitted performance spec, all identical units may be considered unacceptable by the Owner. In such case, the contractor shall provide the Owner with the following:
1. Within one week of notification from the A/E, the contractor shall examine all other identical units making a record of the findings. The findings shall be provided to the A/E within two weeks of the original notice.
 2. Within two weeks of the original notification, the contractor shall provide a signed and dated, written explanation of the problem, cause of failures, etc. and all proposed solutions, which shall include full equipment submittals. The proposed solutions shall not significantly exceed the specification requirements of the original installation.
 3. The A/E will determine whether a replacement of all identical units or a repair is acceptable.
 4. Two examples of the proposed solution will be installed by the contractor and the CA will be allowed to test the installations for up to one week, upon which the CA will decide whether to accept the solution.
 5. Upon acceptance, the contractor and/or manufacturer shall replace or repair all identical items, at their expense and extend the warranty accordingly, if the original equipment warranty had begun. The replacement/repair work shall

proceed with reasonable speed beginning within one week from when parts can be obtained.

- D. Approval: The CA notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made later after review by the CA. The CA recommends acceptance of each test to the Owner and A/E using a standard form. The A/E gives final approval on each test using the same form, providing a signed copy to the CA and the contractor.

3.6 OPERATION AND MAINTENANCE MANUALS

A. Standard O&M Manuals.

- 1. Special requirements for the TCC and TAB contractor are found in Sections 22 08 00 and 23 08 00.

This document requires that the CA review O&M manuals, whereas the LEED-NC credit 3 requires that the CA and CT develop a Systems Manual in addition to the contractor's O&M Manuals. The LEED-NC prerequisite 1 does not have this requirement.

3.7 TRAINING OF OWNER PERSONNEL

- A. The GC shall be responsible for training coordination and scheduling and ultimately for ensuring that training is completed.

- B. The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment.

- 1. The CA shall interview the facility manager and lead engineer to determine the special needs and areas where training will be most valuable. The Owner and CA shall decide how rigorous the training should be for each piece of commissioned equipment. The CA shall communicate the results to the contractor and vendors who have training responsibilities.
- 2. In addition to these general requirements, the specific training requirements of Owner personnel by contractor and vendors is specified in Divisions 22, 23, and 26.
- 3. Each contractor and vendor responsible for training will submit a written training plan to the CA for review and approval prior to training. The plan will cover the following elements:
 - a. Equipment (included in training)
 - b. Intended audience

- c. Location of training
 - d. Objectives
 - e. Subjects covered (description, duration of discussion, special methods, etc.)
 - f. Duration of training on each subject
 - g. Instructor for each subject
 - h. Methods (classroom lecture, video, site walk-through, actual operational demonstrations, written handouts, etc.)
 - i. Instructor and qualifications
4. For the primary HVAC equipment, the TCC shall provide a short discussion of the control of the equipment during the mechanical or electrical training conducted by others.
 5. The CA develops an overall training plan and coordinates and schedules, with the Owner and contractor, the overall training for the commissioned systems. The CA develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The CA recommends approval of the training to the A/E using a standard form. The A/E also signs the approval form.
 6. At one of the training sessions, the CA presents a presentation discussing the use of the blank functional test forms for re-commissioning equipment.
 7. The GC will provide videotaping of the training sessions, with tapes cataloged by the GC, and added to the O&M manuals.
 8. The mechanical design engineer shall at the first training session present the overall system design concept and the design concept of each equipment section. This presentation shall include a review of all systems using the simplified system schematics (one-line drawings) including chilled water systems, heat rejection systems, heating systems, fuel oil and gas supply systems, supply air systems, exhaust system, and outside air strategies.

This requirement meets or exceeds requirements for the LEED-NC credit 3, which requires only that the CA verify that operational personnel training requirements were completed according to the Contract Documents, but does not outline the training required. The LEED-NC prerequisite 1 does not have this requirement.

3.8 DEFERRED TESTING

- A. **Unforeseen Deferred Tests:** If any check or test cannot be completed due to the building structure, required occupancy condition, or other deficiency, execution of checklists and functional testing may be delayed upon approval of the A/E.
- B. **Architect:** These tests will be conducted in the same manner as the seasonal tests as soon as possible. Services of necessary parties will be negotiated.
- C. **Seasonal Testing:** During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) specified in Division 23 shall be completed as part of this contract. The CA shall coordinate this activity. Tests will be executed and documented. and any deficiencies corrected by the appropriate contractor, with facilities staff and the CA witnessing. Any final adjustments to the O&M manuals and as-builds due to the testing will be made.

This requirement differs from, but could meet, the LEED-NC credit 3 requirements for delayed testing and post-occupancy review 8-10 months from completion. The LEED-NC prerequisite 1 does not have this requirement.

3.9 WRITTEN WORK PRODUCTS

- A. The commissioning process generates a number of written work products described in various parts of the Specifications. The Commissioning Plan lists all the formal written work products, describes briefly their contents, who is responsible to create them, their due dates, who receives and approves them, and the location of the specification to create them. In summary, the written products are:

1. Product	2. Developed By
3. Commissioning plan	4. CA
5. Commissioning meeting minutes	6. CA
7. Commissioning schedules	8. GC and CA with other contractors
9. Equipment documentation submittals	10. Contractors
11. Sequence clarifications	12. Contractors and A/E as needed

1. Product	2. Developed By
13. Construction checklists	14. CA (Preliminary in Spec. Revised based on Approved Submittals)
15. Startup and initial checkout plan	16. Contractors and CA (Compilation of existing documents)
17. Startup and initial checkout forms filled out	18. Contractors
19. Final TAB report	20. TAB
21. Issues log (deficiencies)	22. CA with responses provided by contractors
23. Commissioning Progress Record	24. CA
25. Deficiency reports	26. CA
27. Functional test forms	28. CA
29. Filled-out functional tests	30. CA
31. O&M manuals	32. Contractors with review by CA
33. Commissioning record books and CD's	34. CA
35. Overall training plan	36. CA, GC, and Contractors
37. Specific training agendas	38. Contractors
39. Final commissioning report	40. CA
41. Miscellaneous approvals	42. CA

END OF SECTION 01 91 00