

SECTION 01 45 45

COMMISSIONING

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. The purpose of this section is to specify the responsibilities and participation in the commissioning process.
- B. 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.
- C. Commissioning during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:
 - 1. Verify that applicable equipment and systems are installed according to the vendor's recommendations and to industry accepted minimum standards, and that they receive adequate operational checkout by the installing contractors.
 - 2. Verify and document proper performance of equipment and systems.
 - 3. Verify that O&M documentation is complete.
 - 4. Verify that the Owner's operating personnel are adequately trained.
- D. The commissioning process does not take away from or reduce the responsibility of the system designers or installing contractors to provide a finished and fully functioning product.
- E. Work under this contract shall conform to requirements of Division 1, General Requirements, Conditions of the Contract, and Supplementary Conditions. This specification covers commissioning of the systems which are part of this project.
- F. Commissioning work shall be a team effort to ensure that all equipment and systems have been properly installed, function together to meet the design intent, and document system performance parameters for the fine tuning of control sequences and operational procedures.
- G. The commissioning team shall include the Commissioning Authority (CA), representatives of the Owner, vendors, and construction trades. The trades shall include, but not be limited to, piping, plumbing, mechanical, controls, test and balance, electrical, and fire alarm. The lead person for each trade who will actually perform or supervise the work is to be designated as the representative to the commissioning team. Responsibilities for various steps of the commissioning process shall be divided among the commissioning team, as described herein.
- H. Irrigation System installation, start-up, testing, balancing, preparation of O&M Manuals, and operator training are the responsibility of the Division 2 Contractor, including system controls. The commissioning process does not relieve the Division 2 Contractors from the obligations to complete all portions of the work in a satisfactory and fully operational manner.
- I. Elevator System start-up, testing, preparation of O&M Manuals, and operator training are the responsibility of the Division 14 Contractor. The commissioning process does not relieve the Division 14 Contractor from the obligations to complete all portions of the work in a satisfactory and fully operational manner.
- J. Mechanical System installation, start-up, testing, balancing, preparation of O&M Manuals, and operator training are the responsibility of the Division 21-23 Contractor(s), including building automation system controls. The commissioning process does not relieve the Division 21-23 Contractor(s) from the obligations to complete all portions of the work in a satisfactory and fully operational manner.

- K. Electrical System installation, start-up, testing, preparation of O&M Manuals, and operator training are the responsibility of the Division 26 Contractor. The commissioning process does not relieve the Division 26 Contractor from the obligations to complete all portions of the work in a satisfactory and fully operational manner.
- L. Telecommunications and Security Systems installation, start-up, testing, preparation of O&M Manuals, and operator training are the responsibility of the Division 27 Contractor(s). The commissioning process does not relieve the Division 27 Contractor(s) from the obligations to complete all portions of the work in a satisfactory and fully operational manner.

1.02 RELATED SECTIONS

- A. Applicable Sections in Divisions 2, 14, 21-23, 26, and 27.
- B. Section 28 08 00 – Electrical Commissioning.

1.03 SUBMITTALS

- A. The manner in which submittals are processed is outlined in Section 01 33 00 – Submittals.
- B. CA shall submit schedule of equipment and system commissioning and start-up to Contractor, Engineer(s), and Owner.
- C. Contractor shall submit results of vendor’s shop and field tests to CA.
- D. Required documentation as required by Code, the Authority Having Jurisdiction (AHJ), and listed within the Contract Documents and herein.
- E. CA shall submit commissioning plan and procedure as delineated herein to Owner and Contractor.
- F. CA instrumentation calibration records pertaining to test equipment used during commissioning.
- G. At completion of Work, CA shall submit to Owner certification (commissioning report) that equipment and systems have been tested and commissioned, and are in operating condition in accordance with Contract Documents.

1.04 DEFINITIONS

- A. Acceptance Phase: Phase of construction after startup and initial checkout when functional performance tests, O&M documentation review and training occurs.
- 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 consultant (Architect of Record) and sub-consultants who comprise the design team, generally the Mechanical designer/engineer and the Electrical designer/engineer.
- D. Basis of Design: The basis of design is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The basis of design 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 agent, not otherwise associated with the A/E team members or the Contractor, hired by DPS. The CA directs and coordinates the day-to-day commissioning activities. The CA does not take an oversight role like DPS. The CA is part of DPS’s team or shall report directly to DPS.
- F. Commissioning Plan: An overall plan, developed before or after project bidding, that provides the structure, schedule and coordination planning for the commissioning process.
- G. Contract Documents: The documents binding on parties involved in the construction of this project (drawings, specifications, change orders, amendments, contracts, etc.).
- H. Contractor: The General Contractor performing the construction and/or any of the trade contractors performing work under sub-contract with the General Contractor.
- I. Control System: The control system for an individual piece of equipment, the central building energy management control system, or the integrated building automation system, as applicable.
- 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:** Functional tests that are performed later, after substantial completion, due to partial occupancy, equipment, seasonal requirements, design or other site conditions that disallow 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 or vendor's printed documentation (that is, does not perform properly or is not complying with the design intent). (Condition may also be described as non-compliance or non-conformance.)
- 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. **Design Narrative or Design Documentation:** Sections of either the Design Intent or Basis of Design.
- O. **Factory Testing:** Testing of equipment on-site or at the factory by factory personnel with an Owner's representative present.
- P. **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. Functional Performance Tests are performed after pre-functional checklists and startup is complete.
- Q. **General Contractor (GC):** The prime contractor for this project. Generally refers to all the GC's Subcontractors as well. Also referred to as the Contractor, in some contexts.
- R. **Indirect Indicators:** Indicators of a response or condition, such as a reading from a control system screen reporting a damper to be 100% closed.
- 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 dataloggers 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 to minimize the total construction time.

- Z. Pre-Functional Checklist (PC): A list of items to inspect and elementary component tests to conduct to verify proper installation of equipment, provided by the CA to the Subcontractors. Pre-functional checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels acceptable, labels affixed, gauges in place, sensors calibrated, etc.). However, some pre-functional 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 pre-functional refers to before functional testing. Pre-functional checklists augment and are combined with the vendor's start-up checklist. Even without a commissioning process, Contractors typically perform some, if not all, of the pre-functional 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 pre-functional checking, except for larger or more critical pieces of equipment.
- AA. DPS: The contracting and managing authority for the Owner over the design and/or construction of the project.. The Owner's on-site representative in the day-to-day activities of construction. The General Contractor, Commissioning Authority, and Architect/Engineer(s) report to the PM.
- BB. Sampling: Functionally testing only a fraction of the total number of identical or near identical pieces of equipment.
- CC. Seasonal Performance Tests: Functional performance tests that are deferred until the system(s) will experience conditions closer to their seasonal design conditions.
- DD. Simulated Condition: Condition that is created for the purpose of testing the response of a system.
- EE. Simulated Signal: Disconnecting a sensor and using a signal generator to send an amperage, resistance or pressure to the transducer and control system to simulate a sensor value.
- FF. Specifications: The construction specifications of the Contract Documents.
- GG. Startup: The initial starting or activating of dynamic equipment, including executing pre-functional checklists.
- HH. Subcontractors: The Subcontractors to the GC who provide and install building components and systems.
- II. Substantial Completion: The milestone within the construction schedule when a piece of equipment or system is completely installed and ready for startup, commissioning, and operation. It indicates that the item has completed pre-functional testing and is ready for the functional performance tests. It is the start of the warranty period for the equipment included with the system.
- JJ. Test Procedures: The step-by-step process which must be executed to fulfill the test requirements. The test procedures are developed by the CA.
- KK. Test Requirements: Requirements specifying what modes and functions, etc., shall be tested. The test requirements are not the detailed test procedures. The test requirements are specified in the Contract Documents or vendor's printed documentation.
- LL. Trending: Monitoring using the building control system.
- MM. Vendor: Supplier of equipment.
- NN. Warranty Period: Warranty begins at Substantial Completion and extends for at least 24 months, unless specifically noted otherwise in the Contract Documents and accepted submittals.

1.05 RESPONSIBILITIES

- A. The responsibilities of the various parties in the commissioning process are provided in this section as they relate to commissioning. The responsibilities of the Mechanical Contractor, TAB, and Controls Contractor are in Division 21-23, and those of the Electrical Contractor in Divisions 26 and 27.
- B. All Parties:
 1. Follow the Commissioning Plan as prepared by the CA.
 2. Attend commissioning scoping meeting and additional meetings, as necessary.

- C. Architect (or A/E):
 - 1. Construction and Acceptance Phase:
 - a) Perform normal submittal review, construction observation, record drawing preparation, O&M manual preparation, etc., as contracted.
 - b) Provide any design narrative documentation requested by the CA.
 - c) Coordinate resolution of system deficiencies identified during commissioning, according to the Contract Documents.
 - d) Prepare and submit final record drawings for inclusion in the O&M manuals. Review and approve the O&M manuals.
 - 2. Warranty Period:
 - a) Coordinate resolution of design non-conformance and design deficiencies identified during the warranty period.
- D. Mechanical and Electrical Designers/Engineers (of the A/E):
 - 1. Construction and Acceptance Phase:
 - a) Perform normal submittal review, construction observation, record drawing preparation, etc., as contracted. A minimum of one site observation should be completed just prior to system startup.
 - b) Provide any design narrative and sequences documentation requested by the CA. The designers shall assist (along with the Contractor) 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.
 - c) Participate in the resolution of system deficiencies identified during commissioning, according to the Contract Documents.
 - d) Prepare and submit the final record drawings and operating parameters documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.
 - e) From the Contractor's red-line drawings, edit and update one-line diagrams developed as part of the design narrative documentation, and those drawings provided by the vendor as shop drawings for the chilled and hot water, condenser water, domestic water, steam and condensate systems; supply, return and exhaust air systems, and normal and emergency power systems.
 - 2. Warranty Period:
 - a) Participate in the resolution of non-compliance, non-conformance and design deficiencies identified during commissioning during the warranty period.
- E. Commissioning Authority (CA):
 - 1. The CA is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management. The CA may assist with problem-solving, non-conformance or deficiencies, but ultimately that responsibility resides with the General Contractor and the A/E. The primary role of the CA is to develop and coordinate the execution of a testing plan, observe and document performance — that systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. The Contractor(s) will provide all materials, tools, labor, and measuring and test equipment to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CA. Note that the CA does not perform the commissioning activities, that responsibility is retained by the Contractor, Subcontractors and equipment vendors, as applicable.

2. Design Phase:
 - a) Coordinate with the Design Team to develop full commissioning specifications for all commissioned equipment and integrate into the project specifications. Verify that bid documents adequately specify building commissioning, including testing requirements by equipment type. The commissioning specification will include a detailed description of the responsibilities of all parties, details of the commissioning process; reporting and documentation requirements, including formats; alerts to coordination issues, deficiency resolution; construction checklist and startup requirements; the functional testing process; specific functional test requirements, including testing conditions and acceptance criteria for each piece of equipment being commissioned.
 - b) Perform focused reviews of the design, construction drawings and specifications and any bid addendums for the following, but not limited to only these issues:
 - i) Clear design documentation, including detailed and complete sequences of operation.
 - ii) HVAC, lighting, fire control, emergency power, security control system, strategies and sequences of operation for adequacy and efficiency.
 - iii) Ensure the design maximizes the functional needs of the occupants.
 - iv) An HVAC fire and emergency power response matrix that lists all equipment and components (air handlers, dampers, valves, etc.) with their status and action during a fire alarm and under emergency power.
 - v) Access for routine maintenance and operation, including reading gauges, entering doors and panels, observing and replacing filters, coils, etc.
 - vi) Provision within the design for the required isolation valves, dampers, interlocks, piping, etc., to allow for manual overrides, simulating failures, seasons and other testing conditions.
 - vii) Provision within the design of sufficient monitoring points in the building automation system (BAS), and adequate trending and reporting features in the BAS.
 - viii) Provision of pressure and temperature (P/T) plugs close to controlling sensors for verifying their calibration, and pressure gauges, thermometers, and flow meters in strategic areas to facilitate verifying system performance and ongoing O&M.
 - ix) Provision of pressure and temperature (P/T) plugs at less critical areas or on smaller equipment where permanent gauges and thermometers are not required.
 - x) Provision of adequate balancing valves, flow metering, and control stations and control system functions to facilitate and verify reliable test and balance.
 - xi) Clear and complete commissioning specifications for the construction phase.
 - xii) Complete O&M documentation requirements in the specifications.
 - xiii) Complete training requirements in the specifications.
 - c) Coordinate a controls integration meeting where the electrical, mechanical, and controls contractors and the CA discuss integration issues between equipment, systems and disciplines to ensure that integration issues and responsibilities are clearly described in the specifications. [Note: If the controls contractor has not yet been selected until project is bid – this task will occur during the construction phase.]
 - d) Develop a draft commissioning plan as described below, including the pre-functional and functional performance test procedures.
3. Construction and Acceptance Phase:
 - a) Revise, as necessary, the construction phase commissioning plan developed during design, including scope and schedule.
 - b) Coordinate and direct the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.

- c) Coordinate the commissioning work and, with the GC and PM, ensure that commissioning activities are being scheduled into the master schedule.
- d) Review coordination drawings to ensure that trades are making a reasonable effort to coordinate the work.
- e) Plan and conduct a commissioning scoping meeting and other commissioning meetings.
- f) Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.
- g) Before startup, gather and review the current control sequences and interlocks, and work with Contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
- h) Review normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
- i) Review requests for information and change orders for impact on commissioning and Owner's objectives.
- j) Write and distribute pre-functional tests and checklists.
- k) Develop an enhanced start-up and initial systems checkout plan with Subcontractors.
- l) Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.
- m) Witness all of the HVAC piping test and flushing procedure. Document this testing and include the documentation in O&M manuals. Notify DPS Project Manager of any deficiencies in results or procedures.
- n) Witness all of any ductwork testing and cleaning procedures. Document this testing and include the documentation in O&M manuals. Notify DPS Project Manager of any deficiencies in results or procedures.
- o) Approve pre-functional tests and checklist completion by reviewing pre-functional checklist reports and by selected site observation and spot-checking.
- p) Approve systems startup by reviewing start-up reports and by selected site observation.
- q) Review TAB execution plan.
- r) Oversee functional testing of the control system and approve it to be used for TAB, before TAB is executed.
- s) Confirm air and water systems balancing by spot testing, by reviewing completed reports and by selected site observation.
- t) With necessary assistance and review from installing contractors and A/E, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone data logger monitoring, integrated building automation system, or manual functional testing. Submit to PM for review, and for approval if required.
- u) Analyze any functional performance trend logs and monitoring data to verify performance.
- v) Coordinate, witness and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
- w) Maintain a master deficiency and resolution log and a separate testing record. Provide the PM with written progress reports and test results with recommended actions.
- x) Witness performance testing of smoke control systems by others and all other Owner contracted tests or tests by vendor's personnel over which the CA may not have direct control. Document these tests and include this documentation in Commissioning Record in O&M manuals.
- y) Witness testing and other activities called for in Mechanical Commissioning Section 23 08 00 and Electrical Commissioning Section 26 08 00.
- z) Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.

- aa) Oversee and approve the training of the Owner’s operating personnel.
 - bb) Compile and maintain a commissioning record and building systems book(s).
 - cc) Review and approve the preparation of the O&M manuals.
 - dd) Provide a final commissioning report (as described in this specification).
4. Warranty Period:
- a) Coordinate and supervise required seasonal or deferred testing and deficiency corrections.
 - b) Return to the site 3 months prior to end of warranty period and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Interview facility staff and identify problems or concerns they have operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.
- F. DPS Project Manager (PM):
1. Construction and Acceptance Phase:
 - a) Manage the contract of the A/E and of the GC.
 - b) Manage the CA contract.
 - c) Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the Commissioning Plan—Construction Phase.
 - d) Provide final approval for the completion of the commissioning work.
 2. Warranty Period:
 - a) Ensure that any seasonal or deferred testing and any deficiency issues are addressed.
- G. General Contractor (GC or Contractor):
1. Construction and Acceptance Phase:
 - a) Facilitate the coordination of the commissioning work by the CA to ensure that commissioning activities are being scheduled into the master schedule.
 - b) Include the cost of commissioning and startup support in the total contract price, including services of equipment vendors, if applicable.
 - c) Perform specified services with qualified personnel.
 - d) Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CA.
 - e) In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and training.
 - f) Ensure that all Subcontractors execute their commissioning responsibilities according to the Contract Documents and schedule.
 - g) A representative shall attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the commissioning process.
 - h) Furnish materials, tools, labor, and measuring and test equipment required to perform start-up of each respective item of equipment, instrument and system.
 - i) Coordinate the startup of equipment and systems with existing operations or facility equipment so that it does not affect Owner’s operations.
 - j) Coordinate the training of Owner’s personnel in conjunction with the CA.
 - k) Provide instruments required for commissioning operations.
 - i) Make instruments available to A/E to facilitate spot checks during testing.

- ii) Retain possession of instruments; remove from Site at completion of services.
 - iii) Instrumentation for the testing, adjusting, and balancing of the HVAC system shall be provided by the TAB contractor.
 - l) Comply strictly with specified vendor's or Engineer's procedures in starting up and commissioning specified systems.
 - m) Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
 - n) Promptly report to CA any deficiencies noted during performance of commissioning and testing services.
2. Warranty Period:
- a) Ensure that Subcontractors execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
 - b) Ensure that Subcontractors correct deficiencies and make necessary adjustments to O&M manuals and record drawings for applicable issues identified in any seasonal testing.
- H. Vendors (Equipment Suppliers):
- 1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner to keep warranties in force.
 - 2. Assist in equipment testing per agreements with Contractor or Subcontractors.
 - 3. Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these Contract Documents in the base bid price to the Contractor, except for stand-alone datalogging equipment that may be used by the CA.
 - 4. 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.
 - 5. Provide information requested by CA regarding equipment sequence of operation and testing procedures.
 - 6. Review test procedures for equipment installed by factory representatives.

1.06 COMMISSIONING PLAN

- A. The CA shall prepare and submit for review by Engineer and Owner (or Owner's Representative) a commissioning plan that outlines:
- 1. Commissioning personnel training and qualifications.
 - 2. List of vendor's services or startup representatives that will complete startup and commissioning of specific equipment.
 - 3. Preliminary format of final report or documentation that will be completed.
 - 4. Preliminary copy of each report form proposed for use.
 - 5. Schedule of startup for each system or individual piece of equipment.
 - 6. Responsibility of each trade affected by the commissioning as required by each section of this specification and the individual specification sections within the Contract Documents.
 - 7. Requirements for documentation as listed within the Contract Documents and herein.
 - 8. Requirements for documentation of tests and inspections required by Owner, Code or the AHJ.
 - 9. Requirements for the commissioning program during specified operating seasonal or climatic conditions, part and full loads, occupancy, and other variable conditions.
- B. The Owner and Engineer shall review the commissioning plan and provide timely comments to the CA. The CA shall incorporate the comments into the commissioning plan and provide copies to the GC, Owner and Engineer so that commissioning activities can be incorporated into the construction and occupancy schedule for the facility.

PART 2 PRODUCTS

NOT USED

PART 3 EXECUTION

3.01 TESTING EQUIPMENT

- A. All standard testing equipment required to perform startup and initial checkout and required functional performance testing shall be provided by the Division Contractor for the equipment being tested. For example, the Mechanical Contractor of Division 21-23 shall ultimately be responsible for all standard testing equipment for the HVAC system and controls system in Division 21-23, except for equipment specific to and used by TAB in their commissioning responsibilities.
- B. Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents shall be included in the base bid price to the Contractor and left on site, except for stand-alone datalogging equipment that may be used by the CA.
- C. 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:
 - 1. 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.
 - 2. 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.
 - 3. All equipment shall be calibrated according to the vendor's recommended intervals and when dropped or damaged. Calibration tags shall be affixed or certificates readily available.

3.02 REPORTING

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

3.03 START-UP, PRE-FUNCTIONAL 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 simplified pre-functional checklists and startup.
- B. General:
 - 1. Pre-functional checklists are important to ensure that the equipment and systems are connected and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays.
 - 2. Each piece of equipment receives full pre-functional checkout. No sampling strategies shall be used.
 - 3. The pre-functional testing for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.

C. Start-up and Initial Checkout Plan:

1. The CA shall assist the commissioning team members responsible for startup of any equipment in developing detailed start-up plans for all equipment. The primary role of the CA in this process is to ensure that there is written documentation that each of the vendor-recommended procedures have been completed. Parties responsible for pre-functional checklists and startup are identified in the commissioning scoping meeting and in the checklist forms.
2. The CA develops the representative pre-functional checklists and procedures from the individual Specification 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.
3. These checklists and tests are provided by the CA to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.
4. The Subcontractor responsible for the purchase of the equipment develops the full start-up plan by combining (or adding to) the CA's checklists with the vendor's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.
5. The full start-up plan could consist of something as simple as:
 - a) The CA's pre-functional checklists.
 - b) The vendor's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block added by hand at the end.
 - c) The vendor's normally used field checkout sheets.
6. The Subcontractor submits the full startup plan to the CA for review and approval.
7. The CA reviews and approves the procedures and the format for documenting them, noting any procedures that need to be added. If warranted, the Subcontractor will rewrite or revise the procedures to address any concerns noted by the CA. Resolution of any disputes between the Subcontractor and CA will be by the PM.
8. The full start-up procedures and the approval form may be provided to the PM for review and approval.

D. Deficiencies, Non-Conformance and Approval in Checklists and Startup:

1. The Subcontractors shall clearly list any outstanding items of the initial start-up and pre-functional 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 Subcontractor or PM. The CA shall work with the Subcontractors and vendors to correct and retest deficiencies or uncompleted items. The CA will involve the PM, A/E, and others as necessary. The installing Subcontractors or vendors shall correct all areas that are deficient or incomplete in the checklists and tests in a timely manner, and shall notify the CA as soon as outstanding items have been corrected and resubmit an updated start-up report and a Statement of Correction on the original non-compliance report. When satisfactorily completed, the CA recommends approval of the execution of the checklists and startup of each system to the PM using a standard form.
3. Items left incomplete, which later cause deficiencies or delays during functional testing may result in backcharges to the responsible party.

3.04 PHASED COMMISSIONING

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

3.05 FUNCTIONAL PERFORMANCE TESTING

- A. Objectives and Scope:
 - 1. The objective of functional performance testing is to demonstrate that each system is operating according to the documented design intent and Contract Documents and vendor's printed documentation.
 - 2. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation.
 - 3. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems.
- B. Each system shall be operated through all modes of operation (e.g. seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc., shall also be tested.
- C. Development of Test Procedures:
 - 1. 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.
 - 2. Using the testing parameters and requirements in Specification Sections, the CA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system.
 - 3. Each Subcontractor or vendor responsible to execute a test, shall provide limited assistance to the CA in developing the procedures (answering questions about equipment, operation, sequences, etc.).
 - 4. Prior to execution, the CA shall provide a copy of the test procedures to the Subcontractor(s) who shall review the tests for feasibility, safety, equipment and warranty protection. If warranted, the CA will rewrite or revise the procedures to address any concerns noted by the Subcontractor. Resolution of any disputes between the Subcontractor and CA will be by the PM.
 - 5. The CA may submit the test procedures to the A/E for review, if requested.
- D. The CA shall review Owner-contracted, factory testing or required Owner acceptance tests for 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. Redundant testing shall be minimized.
- E. The purpose of any given specific test is to verify and document compliance with the stated criteria of acceptance given on the test form.
- F. The test procedure forms developed by the CA shall include (but not be limited to) the following information:
 - 1. System and equipment or component name(s).
 - 2. Equipment location and ID number.
 - 3. Unique test ID number, and reference to unique pre-functional checklist and start-up documentation ID numbers for the piece of equipment.
 - 4. Date.
 - 5. Project name.
 - 6. Participating parties.
 - 7. A copy of the specification section describing the test requirements.
 - 8. A copy of the specific sequence of operations or other specified parameters being verified.
 - 9. List of test equipment that will be used.
 - 10. Copy of test equipment and instrumentation calibration certification or documentation.
 - 11. Formulas used in any calculations.

12. Required pre-test field measurements.
 13. Instructions for setting up the test.
 14. Special cautions, alarm limits, etc.
 15. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format.
 16. Acceptance criteria of proper performance with a Yes / No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
 17. A section for comments.
 18. Signatures and date block for the CA.
- G. 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 dataloggers. Specification 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, with the approval of the PM. This may require a change order and adjustment in charge to the Owner. The CA will determine which method is most appropriate for tests that do not have a method specified.
- H. Simulated Conditions: Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
- I. Overwritten Values:
1. Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system, shall be allowed, but shall be used with caution and avoided when possible.
 2. 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.
 3. Simulating a condition is preferable, rather than overwriting the value or by altering the appropriate setpoint to see the desired response.
 4. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.
- J. 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.
- K. 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.
- L. 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.
- M. Setup: Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Subcontractor 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 Subcontractor shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.
- N. Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy, e.g., VAV boxes. 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. All major equipment and systems, including boilers, chillers, pumps, air handling units, etc., shall be functionally tested and a sampling strategy shall not be used.
- O. Coordination and Scheduling: The Subcontractors shall provide sufficient notice to the CA regarding their completion schedule for the pre-functional checklists and startup of all equipment and systems. The CA will

schedule functional tests through the PM, GC and affected Subcontractors. The CA shall direct, witness and document the functional testing of all equipment and systems. The Subcontractors shall execute the tests.

- P. In general, functional testing is conducted after pre-functional 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 individual components to subsystems to complete systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is checked.
- Q. 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, Subcontractors and A/E.

3.06 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

- A. Documentation: The CA shall witness and document the results of all pre-functional and functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the PM for review and approval and to the Subcontractors for review. The CA will include the completed testing 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 PM 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 PM.
 - 4. As tests progress and a deficiency are identified, the CA discusses the issue with the executing Subcontractor.
 - a) When there is no dispute on the deficiency and the Subcontractor accepts responsibility to correct it:
 - i) The CA documents the deficiency and the Subcontractor's response and intentions and they go on to another test or sequence. After the discussion, the CA submits the non-compliance reports to the PM for signature, if required. A copy is provided to the Subcontractor and GC. The Subcontractor 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.
 - ii) The CA reschedules the test and the test is repeated.
 - b) If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible:
 - i) The deficiency shall be documented on the non-compliance form with the Subcontractor's response and a copy given to the PM and to the Subcontractor assumed to be responsible.
 - ii) 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 DPS.
 - iii) The CA documents the resolution process.
 - iv) Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the statement of correction on the non-compliance form and provides it to the CA. The CA reschedules the test and the test is repeated until satisfactory performance is achieved.
 - 5. Cost of Retesting:
 - a) The cost for the Subcontractor to retest a pre-functional or functional test, if they are responsible for the deficiency, shall be theirs. If they are not responsible, any cost recovery for retesting costs shall be negotiated with the GC.

- b) For a deficiency identified, not related to any pre-functional checklist or start-up fault, the following shall apply:
 - i) The CA and PM will direct the retesting of the equipment once at no “charge” to the GC for their time. However, the CA’s and PM’s time for a second retest will be charged to the GC, who may choose to recover costs from the responsible Subcontractor.
 - c) The time for the CA and CM to direct any retesting required because a specific pre-functional 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 GC, who may choose to recover costs from the party responsible for executing the faulty pre-functional test.
- 6. The Contractor shall respond in writing to the CA and PM 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 Subcontractor shall not be considered a justified reason for a claim of delay or for a time extension by the General Contractor.
- C. Failure Due to Manufacturing Defect: If 10%, or three (3), whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively) due to manufacturing defect, not allowing it to meet its submitted performance specification, all identical units may be considered unacceptable by the PM. In such case, the Contractor shall provide the Owner with the following:
 - 1. Within one week of notification from the PM, the Contractor or vendor’s representative shall examine all other identical units making a record of the findings. The findings shall be provided to the PM within two weeks of the original notice.
 - 2. Within two weeks of the original notification, the Contractor or vendor 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 PM will determine whether a replacement of all identical units or a repair is acceptable.
 - 4. Two (2) examples of the proposed solution will be installed by the Contractor and the CM will be allowed to test the installations for up to one week, upon which the PM will decide whether to accept the solution.
 - 5. Upon acceptance, the Contractor and/or vendor 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 quickly 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 and by the PM, if necessary. The CA recommends acceptance of each test to the PM using a standard form. The PM gives final approval on each test using the same form, providing a signed copy to the CA and the Contractor.

3.07 FINAL COMMISSIONING RECORD (REPORT)

- A. The final commissioning report shall include an executive summary, list of participants and roles, brief building description, overview of commissioning and testing scope, and a general description of testing and verification methods.
- B. Form of Final Reports:
 - 1. Each individual final reporting form must bear the signature of the person who recorded data and that of the supervisor of reporting organization.
 - 2. When more than one (1) certified organization performs testing and commissioning services, the firm having managerial responsibility shall make submittals.
 - 3. Identify type of instruments, and last date of calibration of each.

4. Record and submit all data measured including airflow, liquid flows, pressure drops, motor amps, voltage at driven equipment, and all other data requested in the individual Specification Sections.
 5. Identify discrepancies that were noted from the Contract Document requirements for each system or equipment.
 6. Acceptance results (performance) with a Yes / No check box to allow for clearly marked whether or not proper performance of each part of the test was achieved.
 7. A section for comments.
 8. Signatures and date block for the CA.
- C. For each piece of commissioned equipment, the report should contain the disposition of the Commissioning Authority regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:
1. Equipment meeting the equipment specifications.
 2. Equipment installation.
 3. Functional performance and efficiency.
 4. Equipment documentation and design intent.
 5. Operator training.
- D. All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc., shall also be listed. Each non-compliance issue shall be referenced to the specific functional test, inspection, trend log, etc. where the deficiency is documented. The functional performance and efficiency section for each piece of equipment shall include a brief description of the verification method used (manual testing, BAS trend logs, data loggers, etc.) and include observations and conclusions from the testing.
- E. The final, signed commissioning report shall be included with the O&M Manuals, with a separate copies provided to the DPS Project Manager, Engineer, and General Contractor.

END OF SECTION 01 45 45