

SECTION 019113

COMMISSIONING

PART 1 GENERAL

1.1 GENERAL REQUIREMENTS

- A. The University reserves the right to hire a third-party Commissioning Agent at the inception of any project. The Commissioning Agent will be responsible for reviewing and commenting on the design concept and design documents prepared by the Design Engineer of Record. The Commissioning Agent ensures conformance with University requirements, Industry Standards and maximizes value to the installation and operation of all mechanical equipment and systems with the Design Engineer of Record. The Commissioning Agent also collaborates with all pertinent trades to ensure conformance with contract document prepared by the Design Engineer of Record. The Design Engineer of Record shall be obligated to work amicably with the Commissioning Agent throughout the design and construction process.

1.2 SUMMARY

- A. Section Includes General Requirements for:
 - 1. Coordination.
 - 2. Commissioning Process.
 - 3. Submittal.
 - 4. Commissioning Submittals.
 - 5. Commissioning Responsibilities.
 - 6. Commissioning Meetings.
 - 7. Scheduling.
 - 8. Reporting.
 - 9. Pre-functional Checklists.
 - 10. Functional Performance Procedures.
 - 11. Functional Performance Test Methods.
 - 12. Documentation, Deficiencies and Test Approvals.
 - 13. Operation and Maintenance Manuals.
 - 14. Demonstration and Training.
 - 15. Deferred Testing.

B. Related Sections:

1. Section 230800 – Commissioning of HVAC Systems.
2. Section 260800 – Commissioning of Electrical systems.
3. Section 220800 – Commissioning of Plumbing systems.

1.3 REFERENCES

A. Associated Air Balance Council:

1. AABC – AABC Commissioning Guideline.

B. American Society of Heating, Refrigerating and Air-Conditioning Engineers:

1. ASHRAE Guideline 1 – The HVAC Commissioning Process.

C. National Environmental Balancing Bureau:

1. NEBB – Procedural Standards for Building Systems Commissioning.

1.4 DESCRIPTION

A. Commissioning:

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the design intent and the University'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.

B. Commissioning Intent:

Commissioning for this project is intended to meet the requirement of the latest version, or version applicable to the project, of LEED Building Design + Construction (BD+C) EA Prerequisite 1: "Fundamental Commissioning of Building Energy Systems" and EA Credit 3: "Enhanced Commissioning". Specific goals for meeting the credits are as follows:

1. Implementation of a Commissioning Plan.
2. Commissioning Authority review of contractor submittals for commissioned equipment.
3. Verify equipment and systems are installed in accordance with manufacturer's instructions, industry accepted minimum standards, and Contract Documents.

4. Verify equipment and systems receive adequate operational checkout by Contractor (pre-functional checks).
 5. Verify and document proper performance of equipment and systems including performance (functional tests).
 6. Verify complete operation and maintenance documentation is delivered to the University.
 7. Verify the University's operating personnel are adequately trained.
- C. Equipment and Systems to be Commissioned: Refer to Section 230800 (Mechanical), Section 260800 (Electrical), Section 220800 (Plumbing), and the Commissioning Plan for equipment and system lists.
- 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. Abbreviations: The following are common abbreviations used in the Specifications and in the Commissioning Plan. Definitions are found in Section 1.11:
- | | |
|---------|-------------------------------------|
| A/E | Architect and design engineers |
| FT | Functional performance test |
| CA | Commissioning authority |
| CC | Controls contractor |
| MC | Mechanical contractor |
| PC | Prefunctional checklist |
| Cx | Commissioning |
| PM | Project manager (of the University) |
| Cx Plan | Commissioning Plan document |
| EC | Electrical contractor |
| TAB | Test and balance contractor |

1.5 COORDINATION

A. Commissioning Team:

The members of the commissioning team consist of the Commissioning authority (CA), the Project Manager (PM), the designated representative of the University's Contractor, the Architect and design Engineers (particularly the mechanical engineer), the Mechanical Contractor (MC), the Electrical Contractor (EC), the TAB representative, the Controls Contractor (CC), any other installing subcontractors or suppliers of equipment; the University's building or plant operator/engineer is also a member of the commissioning team.

B. Management:

The CA is hired by the University directly. The CA directs and coordinates the commissioning activities and reports progress to the Contractor. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents.

C. Scheduling:

The CA will work with the Contractor according to established protocols to schedule the commissioning activities. The Commissioning schedule will be per Section 1.10. The Contractor 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.

The CA will provide the initial schedule of primary commissioning events at the commissioning scoping meeting. The Commissioning Plan provides a format for this schedule. As construction progresses more detailed schedules are developed by the CA. The Commissioning Plan also provides a format for detailed schedules.

1.6 COMMISSIONING PROCESS

A. Commissioning Plan:

The commissioning plan provides guidance in the execution of the commissioning process. Just after the initial commissioning scoping meeting the CA will update the plan which is then considered the “final” plan, though it will continue to evolve and expand as the project progresses. The Specifications will take precedence over the Commissioning Plan.

B. Commissioning Process:

The following narrative provides a brief overview of the typical commissioning tasks construction and the general order in which they occur

1. Commissioning begins with initial commissioning meeting.
2. Conduct progress commissioning meetings throughout construction, to plan, scope, coordinate, schedule future activities and resolve problems.
3. Equipment documentation is submitted to Commissioning Authority concurrent with normal submittal process. Include detailed start-up procedures.
4. Commissioning Authority works with Contractor, equipment manufacturer and system installers to develop startup plans and startup documentation formats, including verification checklists, during verification check and startup process.
5. In general, checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels with verification checklists being completed before functional testing.
6. Equipment and system installers execute and document verification checklists and perform verification check and startup. Commissioning Authority documents checklists and startup were completed according to approved plans.
7. Commissioning Authority develops specific equipment and system functional performance test procedures. Contractor and equipment manufacturer and system installers review procedures.
8. Equipment and system installers execute procedures under direction of and documented by Commissioning Authority.

9. Items of non-compliance in material, installation or setup are corrected at Contractor's expense and system retested.
10. Commissioning Authority reviews operation and maintenance documentation for completeness.
11. Commissioning Authority reviews, approves and coordinates training provided by equipment and system installers and verifies training was completed.
12. Commissioning is completed before Substantial Completion. Commissioning Authority issues commissioning report.
13. Commissioning Authority issues "Systems and Energy Management Manual".
14. Deferred testing is conducted, as specified.

1.7 SUBMITTALS

- A. Furnish submittals for products in accordance with procedure specified in commissioning submittals section below.

1.8 COMMISSIONING SUBMITTALS

- A. Furnish one (1) copy in electronic PDF format of submittals directly to Commissioning Authority for review.
 1. Make submittals for each piece of equipment or system indicated to be commissioned; also provide TAB report submittal.
 2. Make submittals to Commissioning Authority concurrent with submittals to Architect/Engineer. Commissioning Authority will issue comment directly to the A/E. The Commissioning Authority reviews submittals for conformance to Contract Documents as related to the commissioning process for primary purpose of aiding in developing functional testing procedures and secondarily to verify compliance with equipment specifications.
 3. Distribute one (1) copy of approved submittals to Commissioning Authority.
- B. Furnish one copy of preliminary operation and maintenance data manuals to Commissioning Authority for each piece of equipment or system indicated to be commissioned. Submit electronically in PDF format.
 1. Submit required manuals within thirty (30) days after submittals for each piece of equipment or system are approved.
- C. Furnish one (1) copy of equipment startup plan to Commissioning Authority for review and approval. Include the following as minimum:
 1. Manufacturer's standard startup procedures copied from installation manuals.
 2. Manufacturer's standard field checkout sheets.

3. Sensor and actuator calibration procedures including calibration report specifying date and time calibration was performed.
- D. Submit written training plan to A/E and Commissioning Authority for review and approval, a minimum of thirty (30) days prior to conducting training. Include the following in each training session:
 1. Equipment included in training session.
 2. Location of training.
 3. Subjects covered.
 4. Duration of training on each subject.
 5. Instructor for each subject.
 6. Instructional methods to be used.
- E. Contractor's responsibility for deviations in submittals from requirements of the Contract Documents is not relieved by the Commissioning Authority's review.

1.9 COMMISSIONING RESPONSIBILITIES

- A. The responsibilities of various parties in the commissioning process are provided in this section. The responsibilities of the mechanical contractor, TAB and controls contractor are in Section 230800, those of the electrical contractor are in Section 260800 and those of the plumbing contractor are in Section 220800. Their responsibilities are listed here to clarify the commissioning process.
- B. All Parties:
 1. Attend commissioning scoping meeting and additional meetings, as necessary.
- C. Architect (of A/E)
 1. Attend the commissioning scoping meeting and selected commissioning team meetings.
 2. Perform normal submittal review, construction observation, as-built drawing preparation, O&M manual preparation, etc., as contracted.
 3. Provide any design narrative documentation requested by the CA.
 4. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
 5. Prepare and submit final as-built design intent documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.
 6. Coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning.

D. Mechanical, Electrical and Plumbing Designers/Engineers (of the A/E)

1. Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted. One (1) site observation should be completed just prior to system startup.
2. Provide any design narrative and sequences documentation requested by the CA. The designers shall assist (along with the contractors) 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.
3. Attend commissioning scoping meetings and other selected commissioning team meetings.
4. Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
5. Prepare and submit the final as-built design intent and operating parameters documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.
6. From the Contractor's red-line drawings, edit and update one-line diagrams developed as part of the design narrative documentation and those 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 emergency power system.
7. Participate in the resolution of non-compliance, non-conformance and design identified during commissioning during warranty-period commissioning.

E. Commissioning Authority

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 Contractors will provide all tools or the use of tools 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.

1. Coordinates and directs the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.
2. Coordinate the commissioning work and, with the Contractor, ensure that commissioning activities are being scheduled into the master schedule.
3. Revise the commissioning plan as necessary.
4. Plan and conduct a commissioning scoping meeting and other commissioning meetings.

5. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.
6. 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.
7. Review and approve normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
8. Write and distribute pre-functional tests and checklists.
9. Develop an enhanced start-up and initial systems checkout plan with Subs.
10. Perform site visits, as necessary, to observe component and system installations. Attends 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.
11. Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify the University's project manager of any deficiencies in results or procedures.
12. Witness all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify the University's project manager of any deficiencies in results or procedures.
13. Approve pre-functional tests and checklist completion by reviewing pre-functional checklist reports and by selected site observation and spot checking.
14. Approve systems startup by reviewing start-up reports and by selected site observation.
15. Review TAB execution plan.
16. Oversee sufficient functional testing of the control system and approve it to be used for TAB, before TAB is executed.
17. Approve air and water systems balancing by spot testing, by reviewing completed reports and by selected site observation.
18. With necessary assistance and review from installing contractors, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone datalogger monitoring or manual functional testing. Submit to CM for review, and for approval if required.
19. Analyze any functional performance trend logs and monitoring data to verify performance.
20. Coordinate, witness and approve manual functional performance tests installing contractors.

21. Coordinate retesting as necessary until satisfactory performance is achieved.
22. Maintain a master deficiency and resolution log and a separate testing record. Provide the Contractor with written progress reports and test results with recommended actions.
23. Witness performance testing of smoke control systems by others and all other University contracted tests or tests by manufacturer'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.
24. Review equipment warranties to ensure that the University's responsibilities are clearly defined.
25. Oversee and approve the training of the University's operating personnel. The CA will videotape all training sessions for the University's use.
26. Compile and maintain a commissioning record and building systems book(s).
27. Review and approve the preparation of the O&M manuals.
28. Provide a final commissioning report (as described in this section).
29. Coordinate and supervise required seasonal or deferred testing and deficiency corrections.
30. Return to the site at ten (10) months into the twelve (12) month warranty period and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.

F. Contractor – the University's Representative

1. Facilitate the coordination of the commissioning work by the CA, and with the CA, ensure that commissioning activities are being scheduled into the master schedule.
2. Attend a commissioning scoping meeting, other commissioning team meetings and other necessary meetings scheduled by the CA to facilitate the Cx process.
3. Perform the normal review of Contractor submittals.
4. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CA.
5. Review and approve the functional performance test procedures submitted by the CA, prior to testing.
6. When necessary, observe and witness pre-functional checklists, startup and functional testing of selected equipment.

7. Review commissioning progress and deficiency reports.
8. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.
9. Sign-off (final approval) on individual commissioning tests as completed and passing. Recommend completion of the commissioning process to the Project Manager.
10. Coordinate the training of University personnel.
11. Assist the CA as necessary in the seasonal or deferred testing and deficiency corrections required by the specifications.
12. Include the cost of commissioning in the total contract price.
13. In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and training.
14. Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
15. Ensure that all Subcontractors execute their commissioning responsibilities according to the Contract Documents and schedule.
16. Ensure that all Subcontractors execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.
17. Ensure that all Subcontractors correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

G. The University's Project Manager (PM)

1. Manage the contract of the A/E and of the Contractor.
2. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the Commissioning Plan.
3. Provide final approval for the completion of the commissioning work.
4. Ensure that any seasonal or deferred testing and any deficiency issues are addressed.

H. Equipment Suppliers

1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the University to keep warranties in force.
2. Assist in equipment testing per agreements with Subs.

3. Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these Contract Documents in the base bid price to the Contractor, except for stand-alone 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.

1.10 COMMISSIONING MEETINGS

A. Commissioning Authority will make arrangements for meetings, prepare agenda with copies for participants, and preside at meetings.

B. Initial Commissioning Meeting:

1. Commissioning Authority will schedule meeting within sixty (60) days after start of construction. Attendance Required: Commissioning Authority, the University, the University's facility operating personnel, Architect/Engineer, Construction Manager, General Contractor, subcontractors. Require attendance by installers of the following equipment and systems indicated to be commissioned including:
 - a. Mechanical equipment and systems.
 - b. Plumbing equipment and systems.
 - c. Electrical equipment and systems.
 - d. Temperature controls equipment and systems.
2. Agenda:
 - a. Designation of personnel representing parties for commissioning activities.
 - b. Review commissioning process and responsibilities.
 - c. Review commissioning plan development procedures.
 - d. Review required commissioning submittals.
 - e. Present initial commissioning schedule.
3. Commissioning Plan will be issued and reviewed during initial commissioning meeting.

C. Progress Commissioning Meetings:

1. Commissioning Authority will schedule meetings throughout progress of the work at maximum monthly intervals. Initial meetings will coincide with regular project meetings as possible.
 - a. Beginning three (3) months before Submittal Completion, meetings will be scheduled at maximum bi-weekly intervals.

2. Attendance Required: As specified for initial commissioning meeting.
3. Agenda:
 - a. Coordination of commissioning activities.
 - b. Commissioning deficiency resolution.
 - c. Commissioning schedule.
 - d. Planning for future commissioning activities.
- D. Commissioning Authority will record meeting minutes and distribute copies within two (2) days after meeting to participants and those affected by decisions made.

1.11 SCHEDULING

- A. Schedule work to allow adequate time for commissioning activities.
- B. CA will provide durations for Cx of equipment to be incorporated into the Contractor's construction schedule.
- C. The construction schedule will be maintained and updated by the Contractor for issue per contract document requirements.
- D. Identify commissioning milestones, activities, and durations on Project schedule.
 1. Identify the following for each piece of equipment and system including:
 - a. Operation and maintenance manual.
 - b. Pre-Functional Checks and startup.
 - c. Functional performance test.
 - d. Demonstration and training sessions.

1.12 DEFINITIONS

Acceptance Phase - phase of construction after startup and initial checkout when functional performance tests, O&M documentation review and training occurs.

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.

Architect / Engineer (A/E) - the prime consultant (architect) and sub-consultants who comprise the design team, generally the HVAC mechanical designer/engineer and the electrical designer/engineer.

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.

Commissioning Authority (CA) - an independent agent, 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 like the Contractor. The CA is part of the Contractor team or shall report directly to the Contractor.

Commissioning Plan - an overall plan, developed before or after bidding, that provides the structure, schedule and coordination planning for the commissioning process.

Contract Documents - the documents binding on parties involved in the construction of this project (drawings, specifications, change orders, amendments, contracts, etc.).

Control system - the central building energy management control system.

Contractor - the University's representative in the day-to-day activities of construction. In general, the construction management services contractor is hired by the University to assist the government in the overall management of the project including supervising and on-site managing authority over a project's construction. Contractor is the University's on-site representative.

Datalogging - monitoring flows, currents, status, pressures, etc. of equipment using stand-alone dataloggers separate from the control system.

Deferred Functional Tests - FTs 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.

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 (that is, does not perform properly or is not complying with the design intent).

Design Intent - a dynamic document that provides the explanation of the ideas, concepts and criteria that are considered to be very important to the University. It is initially the outcome of the programming and conceptual design phases.

Design Narrative or Design Documentation - sections of either the Design Intent or Basis of Design.

Factory Testing - testing of equipment on-site or at the factory by factory personnel with a University's representative present.

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 pre-functional checklists and startup are complete.

Indirect Indicators - indicators of a response or condition, such as a reading from a control system screen reporting a damper to be one hundred percent (100%) closed.

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”).

Monitoring - the recording of parameters (flow, current, status, pressure, etc.) of equipment operation using dataloggers or the trending capabilities of control systems.

Non-Compliance - see Deficiency.

Non-Conformance - see Deficiency.

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 fifty Fahrenheit (50F) to seventy-five Fahrenheit (75F) to verify economizer operation). See also “Simulated Signal.”

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.

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 Subcontractor. Pre- functional checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels OK, labels affixed, gages 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 (3) 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 manufacturer’s start-up checklist.

Project Manager (PM) - the contracting and managing authority for the University over the design and/or construction of the project, a staff position.

Seasonal Performance Tests - FT that are deferred until the system(s) will experience conditions closer to their design conditions.

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).

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.

Specifications - the construction specifications of the Contract Documents.

Startup - the initial starting or activating of dynamic equipment, including executing pre-functional checklists.

Subcontractors - the subcontractors to the Contractor who provide and install building components and systems.

Test Procedures - the step-by-step process which must be executed to fulfill the test requirements. The test procedures are developed by the CA.

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.

Trending - monitoring using the building control system. Vendor - supplier of equipment.

University-Contracted Tests - tests paid for by the University outside the Contractor's contract and CA does not oversee. These tests will not be repeated during functional tests if properly documented.

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.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 REPORTING

- A. The CA will provide regular progress reports to the PM with increasing frequency as construction and commissioning progresses.
- 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 (about four to six pages, not 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.

3.2 PRE-FUNCTIONAL CHECKLISTS

- A. Commissioning Authority will issue Pre-Functional checklists for each piece of commissioned equipment. Checklist will be completed by the Commissioning Authority with assistance from the Contractor. Completed checklists ensure that equipment and systems are hooked up and fully operational and ready for Functional Testing.

- B. General:

Pre-functional checklists are important to ensure that the equipment and systems are hooked up and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full pre-functional checkout. No sampling strategies are used. 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:

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 manufacturer- 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.

1. The 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 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 manufacturer's detailed start- up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.
3. The subcontractor submits the full startup plan to the CA for review and approval.
4. The CA reviews and approves the procedures and the format for documenting them, noting any procedures that need to be added.

C. Execution of Pre-functional Checklists and Startup:

1. Prior to startup, the Subs and vendors schedule startup and checkout with the Contractor and CA. The performance of the pre-functional checklists, startup and checkout are directed and executed by the CA with assistance from the Contractor. When checking off pre-functional checklists, signatures may be required of other verification of completion of their work.
2. The Subcontractors and vendors shall execute startup and provide the CA with a signed and dated copy of the completed start-up.
3. Only individuals that have direct knowledge and witnessed that a line item task on the pre-functional checklist was actually performed shall initial or check that item off. It is not acceptable for witnessing supervisors to fill out these forms.

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

1. The CA will 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 Contractor within two (2) days of test completion.
2. The CA shall work with the Subs and vendors to correct and retest deficiencies or uncompleted items. The CA will involve the Contractor and others as necessary. The installing Subs 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 Contractor using a standard form.

- F. Sample pre-functional checklists are included at the end of this specification.

3.3 FUNCTIONAL PERFORMANCE TEST PROCEDURES

- A. The objective of functional performance testing is to demonstrate that each system is operating according to the documented design intent and Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems. In general, each system should be operated through all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested.

- B. 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, the CA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each Sub 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 Sub(s) who shall review the tests for feasibility, safety, equipment and warranty protection. The CA may submit the tests to the A/E for review, if requested.

The CA shall review University-contracted, factory testing or required University 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.

The purpose of any given specific test is to verify and document compliance with the stated criteria of acceptance given on the test form.

- C. Complete the following before performing functional tests:

1. Pre-Functional Checklists
2. Control system testing including completion of Permanent Graphics.
3. Air system balancing and water system balancing.
4. All hydronic system flush is complete.
5. All control loops tuned and in automatic.
6. All MEP systems are operating in automatic.
7. BAS graphics and interfaces are programed and connected.

- D. Commissioning Authority will direct, witness, and document results of functional performance tests.

- E. Conduct functional performance tests as specified in Section 230800, Section 260800, Section 220800 and Commissioning Plan.
- F. Demonstrate each piece of equipment and system is operating according to documented design intent and Contract Documents.
- G. Sample functional performance test is included at the end of this specification.

3.4 FUNCTIONAL PERFORMANCE TEST METHODS

- A. 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. The CA may substitute specified methods or require an additional method to be executed, other than what was specified, with the approval of the Contractor. This may require a change order and adjustment in charge to the University. The CA will determine which method is most appropriate for tests that do not have a method specified.
- B. Simulated Conditions:
Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
- C. 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 blower rather than overwriting the value or by altering the appropriate set-point to see the desired response. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.
- D. 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.
- E. Altering Set-Points:
Rather than overwriting sensor values, and when simulating conditions is difficult, altering set-points to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below fifty Fahrenheit (55F), when the outside air temperature is above fifty Fahrenheit (55F), temporarily change the lockout set-point to be two Fahrenheit (2F) above the current outside air temperature.
- F. 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 pre-functional testing.
- G. Setup:

Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Sub executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions.

At completion of the test, the Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.

H. Coordination and Scheduling:

The Subs 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 Contractor and affected Subcontractors. The CA shall direct, witness and document the functional testing of all equipment and systems. The Subs shall execute the tests.

In addition to the Construction Schedule in section 1.10, Contractor shall provide CA with four (4) week look- ahead schedule.

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 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.

I. Problem Solving:

The CA will recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the Contractor, Subcontractors and A/E.

3.5 DOCUMENTATION, DEFICIENCIES AND TEST APPROVALS

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 Contractor for review and approval and to the Subcontractors for review. The CA will include the filled-out forms in the O&M manuals.

B. Deficiencies:

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 Contractor on a standard issues log.
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 in the issues log.
3. Every effort will be made to expedite the testing process and Subcontractor's 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 Contractor.

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 Sub 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 day's work, the CA submits the non-compliance reports to the Contractor for signature, if required. A copy is provided to the Sub and CA. The Sub corrects the deficiency and notifies the Contractor and CA that the equipment is ready to be retested.
 - 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 issues log with the response and a copy given to the Contractor and to the Subcontractor representative 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 the Project Manager.
 - iii. The CA documents the resolution process.
 - iv. Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency and notifies the Contractor and CA that the equipment is ready to be retested. 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 check 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 Contractor.
 - b. For a deficiency identified, not related to any pre-functional checklist or start-up fault, the following shall apply: The CA and Contractor will direct the retesting of the equipment once at no "charge" to the Contractor for their time. However, the CA's and Contractor's time for a second retest will be charged to the Contractor, who may choose to recover costs from the responsible Subcontractor.
 - c. The time for the CA and Contractor 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 Contractor, 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 Contractor 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 issues log 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 prime contractor.

C. Failure Due to Manufacturer Defect:

If ten percent (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 spec, all identical units may be considered unacceptable by the Contractor or PM. In such case, the Contractor shall provide the University with the following:

1. Within one (1) week of notification from the Contractor or PM, or manufacturer's representative shall examine all other identical units making a record of the findings. The findings shall be provided to the Contractor or PM within two (2) weeks of the original notice.
2. Within two (2) weeks of the original notification, the Contractor or manufacturer 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 Contractor or 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 will be allowed to test the installations for up to one (1) week, upon which the PM 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.

E. 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 Contractor, if necessary. The CA recommends acceptance of each test to the Contractor using a standard form. The Contractor gives final approval on each test using the same form, providing a signed copy to the CA.

3.6 OPERATION AND MAINTENANCE MANUALS

A. Standard O&M Manuals:

The CA reviews the O&M manuals, documentation and redline as-builts for systems that were commissioned to verify compliance with the Specifications. The CA recommends approval and acceptance of these sections of the O&M manuals to the PM. The CA also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated.

B. Commissioning Record:

The CA will compile, organize and index the following commissioning data by equipment into labeled, indexed and tabbed, three-ring binders and deliver it to the GC, PM, and CM, to be included with the O&M manuals. The correspondence, meeting minutes and progress reports, miscellaneous notes, etc. will not be retained into this record and the O&M manuals. The format of the manual follows:

General:

Tab I-1 Commissioning Plan

Tab I-2 Final Commissioning Report

Tab I-3 Issues Log Equipment Specific:

Tab 01 System Type 1:

Sub-Tab A Design narrative and criteria, sequences, approvals for Equipment 1

Sub-Tab B Start-up plan and report, approvals, corrections, blank pre- functional checklists
Colored Separator Sheets – for each equipment type.

Sub-Tab C Functional tests (completed), trending and analysis, approvals and corrections,
training plan, record and approvals, blank functional test forms and a
recommended re-commissioning schedule.

Tab 02 System Type 2...repeat as per “System Type 1” for all additional systems

C. Final Report Details:

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. 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.

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.

3.7 DEMONSTRATION & TRAINING

- A. University training and orientation on equipment and systems provided by the Contractor is accomplished in three general steps using three (3) forms.
1. Overall Plan: After reviewing the specifications, and after interviewing facility staff, if necessary, the University and CA fill out a table listing all the equipment for which training or orientation will be provided. This form lists, among other things, the type and number of

trainees, rigor of training desired by the University, the primary responsible subcontractor, the trainer's company and columns for tracking training agendas. The CA provides this form to the Contractor for reference.

2. Approved O&Ms and As-Built are mandatory for Training and will be required as part of the agenda.
3. Specific Training Agendas: For each piece of equipment or system for which training is provided, the University and CA will approve the training agenda.

The Contractor has the trainer submit an agenda describing the subjects covered, duration of each subject and the methods that will be used in the training, along with the name and qualifications of the trainer(s). The Contractor submits the agenda to the University and CA. The University and CA review the agenda; make comments; approve the form subject to the comments; and submit back to the Contractor. The Contractor provides the approved agenda to the trainer to use during the training. The trainer provides a copy of the agenda to each trainee.

4. Training Record: For each piece of equipment, prior to training, the Contractor provides each trainer. On this form, the trainer documents each training session (duration and general subjects covered). The trainer signs for the session and obtains the signature of each trainee. The trainer also checks off subjects covered on the Agenda. When the training is complete, the Contractor provides a copy of the Training and Orientation Record and the trainer's Agenda to the University and CA. The University and CA review and make final approval by signing it.
- B. Commissioning Authority will develop criteria for determining training was satisfactorily completed, including attending training sessions.
- C. The Commissioning Authority will videotape all training sessions for University use.

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 PM. These tests will be conducted in the same manner as the seasonal tests as soon as possible. Services of necessary parties will be negotiated.

B. Seasonal Testing:

During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) shall be completed as part of this contract. The CA shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the appropriate Subs, with facilities staff and the CA witnessing. Any final adjustments to the O&M manuals and as-builts due to the testing will be made.

3.9 ACCEPTANCE

A. The following list of items needs to be complete before University acceptance of building:

1. Equipment Start-up, Programing complete.

2. Equipment Test and Balance complete.
3. All hydronic system flush is complete.
4. All building air flush out is complete.
5. All control loops tuned and in automatic.
6. Pre-functional checklist completed, verified and signed by all parties.
7. Final Certified Test and Balance report has been provided to the University (approved by EOR).
8. All identified Test and balance or Pre-functional checklist issues resolved.
9. Trends setup and are shown to be stable.
10. All MEP systems are operating in automatic.
11. BMS graphics and interfaces are programed and connected.
12. Lighting Controls full programed and in automatic.
13. University/Operator training is complete and approved.
14. Warranty information provided to University.
15. Operations and Maintenance manuals have been reviewed and approved.
16. All open/outstanding items on the commissioning issues log are resolved.
17. No open or outstanding MEP related RFIs are open or pending with the engineer.
18. Engineer punch is complete, items resolved.

END OF SECTION