

## 230800 COMMISSIONING OF HVAC

### Part 1 – GENERAL

#### 1.1 Description

A. This section details the guidelines and expectations for the Commissioning of a new or upgraded HVAC system on Johns Hopkins University Homewood Campus. This systematic process ensures that all building systems perform interactively according to the design, intent and owner's operational needs. This is achieved starting in the design and documenting phase, then continued through construction and to the acceptance and warranty period with monitored verification of performance. The commissioning process shall include functions of system documentation, equipment startup, control system calibration, testing and balancing, and performance testing, verification and training.

B. Commissioning during the construction process 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 manufacturer's recommendations and to both JHU and industry accepted minimum standards. The systems shall receive adequate operational checkout by installing contractors prior to approval.

2. Verify and document proper performance of equipment and systems.

3. Verify that O&M documentation left on site is complete.

4. Verify that the owner's operating personnel are adequately trained.

5. Review system's performance during warranty period.

C. Abbreviations: The following are common abbreviations used in the Specifications and in the Commissioning Plan.

1. A/E: Architect and Design Engineers

2. CA: Commissioning Agent

3. CC: Controls Contractor

4. CM: Construction Manager (Owner's representative)

5. Cx: Commissioning

6. EC: Electrical Contractor

7. FT: Functional performance test

8. GC: General Contractor

9. MC: Mechanical Contractor

- 10. PC: Prefunctional Checklist
- 11. PM: Project Manager (of the Owner)
- 12. Subs: Subcontractors to General TAB Test
- 13. TAB: Testing and Balancing

## 1.2 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.

Basis of Design - documentation of the primary design the systems, components, conditions and methods chosen to meet the intent.

Commissioning Agent (CA) - an independent agent, not associated with the A/E team members or the Contractor. The CA directs and coordinates the day-to-day commissioning activities. The CA does not take an oversight role and shall report directly to the PM.

Functional Performance Test (FT) - test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods.

Pre-functional Checklist (PC) - list of items to inspect and component testing conducted to verify proper installation of equipment

Seasonal Performance Tests - FT that is deferred until the system(s) experience peak 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.

Testing, Adjusting and Balancing (TAB) - measuring and adjusting air and water flows to meet design requirements.

## 1.3 Submittals

A. The Commissioning Plan is binding on the Contractor. The commissioning plan provides guidance in the execution of the commissioning process. The CA shall provide initial and final commissioning plan for review.

1.4 Responsibilities: All Parties shall follow Commissioning Plan and shall attend commissioning related meetings.

### A. Architect (of A/E)

- 1. Provide any design narrative documentation requested by the CA.
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2. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.

**B. Mechanical and Electrical Designers/Engineers (of the A/E)**

1. Provide any design narrative and sequences documentation requested by the CA.

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. Review and approve the pre-functional checklists for major pieces of equipment for sufficiency prior to their use.

4. Review, and approve the functional test procedure forms for major pieces of equipment for sufficiency prior to their use.

5. Correct deficiencies and schedule retesting of equipment.

**C. Commissioning Agent (CA):**

1. Develop and coordinate the execution of a testing plan.

2. Observe and document that systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents.

3. Supply and install any specific equipment required for commissioning testing.

4. 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.

5. Write and distribute pre-functional tests and checklists.

6. Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document testing and include the documentation in O&M manuals. Notify project manager of any deficiencies in results or procedures.

7. Witness all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Document testing and include the documentation in O&M manuals. Notify project manager of any deficiencies in results or procedures.

8. Approve pre-functional tests and checklist completion by reviewing pre-functional checklist reports and by selected site observation and spot checking.

9. Oversee sufficient functional testing of the control system and approve it to be used for TAB, before TAB is executed.

10. Write the functional performance test procedures for equipment and systems. Submit to PM for review and approval.

11. Maintain a master deficiency and resolution log as well as a separate testing record.
12. Provide the PM with written progress reports and test results with recommended actions.
13. Provide a final commissioning report.

#### D. General Contractor (GC)

1. Facilitate the coordination of the commissioning work by the CA ensure that commissioning activities are being scheduled into the master copy.
2. Furnish a copy of all construction documents, addenda, change orders, approved submittals and shop drawings related to commissioned equipment to the CA.
3. Coordinate the training of owner personnel.
4. Provide all tools or the use of tools to start, check-out and functionally test equipment and systems

## Part 2 – PRODUCTS

### 2.1 Test Equipment

A. All standard testing equipment required to perform startup, initial checkout and required functional performance testing shall be provided by the contractor for the equipment being tested.

B. Data-logging equipment and software required to test equipment will be provided by the CA, but shall not become the property of the owner.

## Part 3 – EXECUTION

### 3.1 Meetings

A. Scoping Meeting: prior to the commencement of construction, the CA will schedule, plan and conduct a commissioning scoping meeting with the entire commissioning team in attendance. Meeting minutes will be distributed to all parties by the CA. Final commissioning plan shall be generated from meeting for approval.

### 3.2 Reporting

A. The CA will provide reports to the PM based on the results found during the aforementioned observations, testing and inspections.

### 3.3 Start-up, Pre-functional Checklists and Initial Checkout

A. Start-up and Initial Checkout Plan. The CA shall assist the commissioning team members responsible for start-up 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. These checklists indicate required procedures to be executed as part of startup and initial checkout of the systems and the party responsible for their execution.

2. The CA will provide generic checklists, the content of which must be reviewed by the Contractor and supplemented with manufacturer specific requirements. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.

3. The 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.

4. The full start-up plan could consist of something as simple as:

a. The CA's pre-functional checklists.

b. The manufacturer's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block at the end.

c. The manufacturer's normally used field checkout sheets.

5. The subcontractor submits the full startup plan to the CA for review and approval.

6. The CA reviews and approves the procedures and the format for documenting them, noting any procedures that need to be added.

## B. Execution of Pre-functional Checklists and Startup.

1. Four weeks prior to startup, the Subs and vendors schedule startup and checkout with the PM, GC and CA. The performance of the pre-functional checklists, startup and checkout are directed and executed by the Sub or vendor. When checking off pre-functional checklists, signatures may be required of other Subs for verification of completion of their work.

2. The CA shall observe, at minimum, the procedures for each piece of primary equipment, unless there are multiple units, (in which case a sampling strategy may be used as approved by the PM). In no case will the number of units witnessed be less than four on any one building, nor less than 20% of the total number of identical or very similar units.

3. For lower-level components of equipment, (e.g., VAV boxes, sensors, controllers), the CA shall observe a sampling of the pre-functional and start-up procedures.

4. The Subs and vendors shall execute startup and provide the CA with a signed and dated copy of the completed start-up and pre-functional tests and checklists.

5. 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.

### C. Deficiencies, Non-Conformance and Approval in Checklists and Startup

1. The Subs 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 Sub or PM. The CA shall work with the Subs and vendors to correct and retest deficiencies or uncompleted items. The CA will involve the PM 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 addressed, the CA recommends approval of the execution of the checklists and startup of each system to the PM.

3. Items left incomplete, which later cause deficiencies or delays during functional testing may result in back charges to the responsible party.

### 3.4 Functional Performance Testing

A. Objectives and Scope. 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. 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. Testing is to verify and document compliance with the stated criteria of acceptance given on the test form. 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. Each Sub or vendor responsible to execute a test shall provide 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 owner-contracted, factory testing or required owner acceptance tests which the CA is not responsible to oversee, including documentation format, and shall determine what further testing or format changes may be required to comply with the Specifications. Redundancy of testing shall be minimized. 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. Formulas used in any calculations
10. Required pre-test field measurements
11. Instructions for setting up the test
12. Special cautions, alarm limits, etc.
13. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format
14. 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
15. A section for comments
16. Signatures and date block for the CA

## C. Test Methods

1. Simulated Conditions. Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
  2. Overwritten Values. Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading shall be allowed, but to be used with approved exceptions. 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 setpoint to see the desired response). Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.
  3. 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.
  4. Altering Setpoints. When simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, verify the AC compressor lockout works at an outside air
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temperature below 55° F, when the outside air temperature is above 55° F, by temporarily changing the lockout setpoint to be 2° F above the current outside air temperature.

D. 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, Subs and A/E.

### 3.5 Documentation, Non-conformance and Approval of Tests

#### A. 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. The deficiency and resolution shall 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. 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.

### 3.6 Operation and Maintenance Manuals

#### A. Commissioning Record in O&M Manuals

1. The CA is responsible to compile, organize and index the following commissioning data by equipment into labeled, indexed and tabbed, three-ring binders and deliver it to the GC, to be included with the O&M manuals. Three copies of the manuals will be provided. The format of the manuals shall be:

1. Commissioning Plan

2. Final Commissioning Report

3. System Type 1 (chiller system, packaged unit, boiler system, etc.)

a. Sub-Tab: Design narrative and criteria, sequences, approvals for Equipment.

b. Sub-Tab: Startup plan and report, approvals, corrections, blank pre-functional checklists, Colored Separator Sheets-for each equipment type (fans, pumps, chiller, etc.).

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

4. System Type 2 repeat as per System 1.

5. Other documentation will be retained by the CA.

### 3.7 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. 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.

### 3.8. Written Work Products

A. The commissioning process generates a number of written work products described in various parts of the Specifications. In summary, the written products are:

<u>Product</u>	<u>Developed By</u>
1. Final Commissioning Plan	CA
2. Meeting Minutes	CA
3. Commissioning Schedules	CA with GC and CM
4. Pre-functional checklists	Subs and CA
5. Startup and initial checkout plan	Subs and CA
6. Startup and initial checkout forms filled out	Subs
7. Commissioning Progress Report	CA
8. Commissioning record book	CA