

**SECTION 01 91 13****GENERAL COMMISSIONING REQUIREMENTS****PART 1 – GENERAL****1.1 OBJECTIVE**

- A. The objective of building commissioning at Dartmouth College is to verify that the owner's project requirements (OPR) are met during project planning, design, construction, and turnover.
- B. Commissioning services shall be provided by an Independent Commissioning Authority for projects where the MEP scope of work exceeds \$1 Million in value.

**1.2 DESCRIPTION**

- A. Commissioning: Commissioning is a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meet defined objectives and criteria. Ideally the Commissioning process begins at project inception (during the conceptual design phase) and continues through the warranty phase of the project, and beyond. The commissioning process includes specific tasks to be conducted during each phase in order to verify that design, construction, and training meets the owner's project requirements. 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.
- B. Commissioning shall:
  - 1. Verify that applicable equipment and systems are installed according to the contract documents, manufacturer's recommendations, and industry accepted minimum standards and that they receive adequate operational checkout by installing contractors.
  - 2. Verify and document proper performance of equipment and systems.
  - 3. Verify that O&M documentation provided to Owner is complete.
  - 4. Verify that the owner's operating personnel are adequately trained.

**1.3 SUMMARY**

- A. This section includes general requirements that apply to the implementation of the commissioning process without regard to specific systems, assemblies, and components.

**1.4 RELATED STANDARDS**

- A. The Commissioning Authority (CA) shall conduct a commissioning process capable of verifying that the facility and its systems meet the Owner's Project Requirements (OPR) as described in current ASHRAE Guideline 0-20XX *The Commissioning Process* and ASHRAE Standard 202-20XX *Commissioning Process for Buildings and Systems*.
- B. The CA shall refer to ASHRAE Guideline 1.1-20XX *HVAC&R Technical Requirements for the Commissioning Process* for technical requirements related to the application to ASHRAE Guideline 0.

## 1.5 RELATED WORK

- A. All the following sections apply to the Work of this section. This list does not limit the work that may be required by the CM under additional specification section for the completion of the Commissioning process.
  - 1. Section 017700 - CONTRACT CLOSEOUT
  - 2. Section 140001 - ELEVATORS
  - 3. Section 210001 - FIRE PROTECTION
  - 4. Section 220001 - PLUMBING
  - 5. Section 230001 - HEATING, VENTILATING AND AIR CONDITIONING.
  - 6. Section 260001 - ELECTRICAL WORK

## 1.6 COMMISSIONING TEAM

- A. Commissioning Team: The members of the commissioning team consist of the contracted Commissioning Authority (CA), the owner's representative/construction manager (CM), the general contractor (GC), the architect and design engineers, the mechanical contractor (MC), the electrical contractor (EC), the testing and balancing (TAB) contractor, the control contractor (CC), the facility operating staff, and any other installing subcontractors or suppliers of equipment. The contracted commissioning agent is hired by the owner directly. The CA directs and coordinates the project commissioning activities and the reports to the owner. All team members work together to fulfill their contracted responsibilities and meet the objectives of the contract documents.
- B. Members appointed by general contractor: Individuals, each having authority to act on behalf of the entity he or she represents, explicitly organized to implement the commissioning process through coordinated actions. The commissioning team shall consist of, but not be limited to, project superintendent, representatives of general contractor, subcontractors, installers, suppliers, and specialists deemed appropriate by the CA.
- C. Members appointed by owner:
  - 1. CA - An entity hired directly by the owner who leads, plans, schedules, and coordinates the commissioning team to implement the commissioning process.
  - 2. Representatives of the facility user and operation and maintenance personnel.
  - 3. Architect and engineering design professionals.
- D. Each member of the commissioning team must attend commissioning meetings in accordance with the Commissioning Authority's schedule.

## 1.7 COMMISSIONING PLAN

- A. The CA will develop the commissioning plan which shall be included in the project schedule when approved by the owner or CM. The following narrative provides a brief overview of the typical commissioning tasks and the general order in which they occur.
  - 1. The Commissioning Authority (CA) will work with the owner and design team to develop and maintain Owner's Project Requirements (OPR) document.

2. CA will review basis of design and DD & CD design documents during the design phase and provide feedback to design team regarding the project's ability to meet the OPR.
3. The CA will develop a commissioning plan that will be updated as the project progresses.
4. Commissioning during construction begins with a scoping meeting conducted by the CA wherein the commissioning process is reviewed with the commissioning team members.
5. Additional meetings scheduled by the CA will be required throughout construction, to plan, scope, coordinate, and schedule future activities and resolve problems.
6. Equipment documentation is submitted to the Engineer during normal submittals, including detailed start-up procedures. The CA will review and comment on applicable items.
7. The contractor and subcontractors develop and submit startup plans to the CA for review and approval prior to startup.
8. The contractor ensures that subcontractors execute construction checklists, pre-functional checklists, perform startup, and initial checkout. The CA reviews and verifies that TAB, construction checklists, and startup were completed according to the approved plans. The CA approves TAB, checklists, startup plans, and may witness start-up and pre-functional tests of selected equipment.
9. The CA with assistance from the contractor and subcontractors, develops functional test procedures for specific equipment and equipment systems. Forms and procedures are to be submitted for approval by Architect / Engineer (A/E) and owner prior to testing.
10. The functional test procedures are executed by the contractor, under the direction of, and documented by the CA.
11. Items of non-compliance in material, installation, or setup are corrected at the contractor's expense, including the re-test to prove compliance.
12. The contractor shall submit O&M documentation to CA for review of completeness. The CA will provide commissioning records for the O&M manual.
13. The CA develops procedures, reviews, pre-approves, coordinates, and implements owner training provided by the contractor.
14. The CA assembles all project documentation into Final Report and Systems Manuals
15. Commissioning is completed before Substantial Completion.
16. Deferred testing is conducted, as specified or required.

## 1.8 FUNCTIONAL PERFORMANCE TEST

- A. A Functional Performance Test (FPT) can be conducted for a system after the GC has submitted complete quality control documentation to the CA indicating that it is ready to do so. Complete construction checklists, startup documentation, preliminary TAB reports, and any other relevant documentation from the GC and its subcontractors shall be compiled and submitted to the CA for review prior to scheduling a FPT. The intent of the FPT is for the CA to verify that the contractor has delivered a quality and functional system that has already undergone a thorough internal quality control process. The FPT as conducted by the CA should not serve as an integral part of the GC's quality control process. The GC shall verify that the equipment and systems work as intended prior to the FPT. Before the FPT, the GC shall provide the Commissioning Authority with the following applicable documents:

1. Construction checklists
2. Startup reports
3. Preliminary O&M's
4. As-built drawings (if significantly different than 100% CDs)
5. Preliminary TAB report (if applicable)

## **1.9 FUNCTIONAL COMPLETION**

- A. The Commissioning Authority will submit a final commissioning report when all Commissioning requirements have been met.

## **1.10 COMMISSIONING SCHEDULE AND COORDINATION**

- A. The commissioning schedule is a component of the commissioning plan that is generated and maintained by the CA, or by the Construction Manager in coordination with the CA. The schedule is a working document that includes all significant activities and milestones related to the commissioning process. It insures that the entire project team is on the same page with commissioning activities that need to be incorporated in other project schedules.
- B. The CA shall coordinate the commissioning activities through the construction manager. All members shall work together to fulfill their contracted responsibilities and meet the objectives of the construction documents.
- C. The CA, through the CM, will provide sufficient notice to the contractor and subcontractors for scheduling commissioning activities with respect to the owner's participation. The contractor will integrate all commissioning activities into the overall project schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process.
- D. The CM's schedule for construction shall include commissioning to be complete prior to substantial completion and owner occupancy (except for seasonal tests).

## **1.11 RELATED WORK**

- A. A commissioning plan will be developed by the Commissioning Authority. Contractors are obligated to assist the Commissioning Authority in preparing the commissioning plan by providing all necessary information pertaining to the actual equipment and installation.

## **1.12 WORK TO RESOLVE DEFICIENCIES**

- A. Corrective work shall be completed in a timely fashion to permit timely completion of the commissioning process.

## **1.13 SEASONAL COMMISSIONING AND OCCUPANCY VARIATIONS**

- A. Seasonal commissioning pertains to testing under full load conditions during peak heating and peak cooling seasons, as well as part-load conditions in the spring and fall. Initial commissioning will be done as soon as contract work is completed regardless of season.

Subsequent commissioning may be undertaken at any time thereafter to ascertain adequate performance during the different seasons.

- B. All equipment and systems will be tested and commissioned in a peak season to observe full-load performance. Each Contractor and supplier will be responsible to participate in the initial and the alternate peak season test of the systems required to demonstrate performance, as scheduled by the Commission Agent, with three-day (minimum) advance notification.
- C. Subsequent commissioning may be required under conditions of minimum and/or maximum occupancy or use.

#### 1.12 COMMISSIONING COMPLETION

- B. Prerequisites to functional completion
  - 1. All TAB work and commissioning activities (except for planned seasonal testing) must be complete prior to Functional Completion, unless approved in writing by the CA. This includes, but is not limited to:
    - a. Completed and signed start-up and pre-functional checklist documentation
    - b. Requested trend log data
    - c. Submission of final approved TAB report
    - d. Completion of all functional testing
    - e. Required training of owner personnel completed and approved
    - f. Submission of the approved O&M manuals, documents and electronic media
    - g. All identified deficiencies have been corrected or are approved by the Dartmouth Project Manager to be excepted from this milestone.
- C. The CM will determine the date of Functional Completion after reviewing the Commissioning Authority's recommendation for Functional Completion.
- D. Commissioning activities are non-compensable and cannot be a cause for delay claims.

#### 1.14 RE-TESTING

- A. It is the responsibility of the contractor to ensure that equipment and systems work prior to functional performance testing. ***If the retesting effort exceeds the budgeted CA retesting hours due to lack of completion by the contractor, the contractor shall reimburse all associated costs for the extraordinary participation of the CA, A/E, and Owner's staff.***

### PART 2 – PRODUCTS

#### 2.1 TEST EQUIPMENT

- A. All standard testing equipment required to perform startup, initial checkout, and required performance testing shall be provided by the contractor for the equipment being tested.
- B. Special equipment, tools, and instruments required for testing equipment according to the contract documents shall be included in the contractor's base bid price and shall be turned over to the owner at Project close-out.

- C. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance within the tolerances specified in the specifications. If not otherwise noted, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration to NIST traceable standards within the past year to an accuracy of 0.5 degree F and a resolution of + or - 0.1 degree F. Pressure sensors shall have an accuracy of + or - 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals and when dropped or damaged. Calibration tags shall be affixed or certificates readily available.

## 2.2 TEST EQUIPMENT - PROPRIETARY

- A. Proprietary test equipment required by the manufacturer, whether specified or not, shall be provided by the manufacturer of the equipment. Manufacturer shall provide the test equipment and necessary training to use it.
- B. Identify the proprietary test equipment required in the test procedures submittals and in a separate list of equipment to be included in the operations and maintenance manuals.

## PART 3 – EXECUTION

### 3.1 DESIGN AND CONSTRUCTION TEAM RESPONSIBILITIES

- A. The responsibilities of all parties in the commissioning process are provided in this section.
- B. All Parties:
  - 1. Attend commissioning scoping meeting and additional meetings, as necessary.
- C. Architect (of A/E):
  - 1. *Design Phase*
    - a. Work with owner, engineer and commissioning Authority to develop the owners project requirements document.
    - b. Perform normal submittal review, construction observation, as-built drawing preparation, O&M manual preparation, etc., as contracted.
  - 2. *Construction Phase*
    - a. Attend the commissioning scoping meeting and selected commissioning team meetings.
    - b. Perform normal submittal review, construction observation, as-built drawing preparation, O&M manual preparation, etc., as contracted.
    - c. Provide any design narrative documentation requested by the CA.
    - d. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
    - e. Prepare and submit design intent documentation clarifications for inclusion in the O&M manuals. Review and approve the O&M manuals.
  - 3. *Post Construction Phase*

- a. Coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning.
- D. Design Engineer:
- 1. *Design Phase*
    - a. Work with owner, architect and commissioning Authority to develop the owners project requirements document.
  - 2. *Construction Phase*
    - a. Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted. 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 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.
    - c. Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
- E. Commissioning Authority (CA):

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 Construction Manager and the A/E. The primary role of the CA is to 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, checkout and functionally test equipment and systems.

- 1. *Design Phase*
  - a. Work with owner, engineer and architect, to assist in the development of the owner's project requirements document.
  - b. Develop Commissioning Plan to define the Commissioning process and roles and responsibilities for the project.
  - c. Review the project plans and specifications with respect to their completeness in all areas relating to the commissioning process. This includes verifying that the OPR has been met, and that there are adequate devices included in the design to properly test the systems and assemblies, and to document the performance of each piece of equipment, system, or assembly.
  - d. Develop the Commissioning Specifications defining the commissioning requirements for the contractors.
- 2. *Construction Phase*

- a. 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.
- b. Submit commissioning schedule to CM, MEC, TT, and A/E to ensure that commissioning activities are being scheduled into the master schedule.
- c. Plan and conduct a commissioning scoping meeting and other commissioning meetings.
- d. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures. Assist in facilitating and organizing the equipment data collection for Dartmouth's computerized maintenance management system.
- e. Before startup 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.
- f. Review systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
- g. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress.
- h. Verify systems startup by reviewing start-up reports and by selected site observation.
- i. Review TAB execution plan.
- j. Verify air and water systems testing by witnessing selected leak/pressure testing, spot check balancing, and by reviewing completed reports and by selected site observation.
- k. 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 data logger monitoring or manual functional testing.
- l. Analyze any functional performance trend logs and monitoring data to verify performance.
- m. Coordinate, witness, and approve functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
- n. Maintain a master deficiency and resolution log and a separate testing record. Provide the CM, MEC, TT, and A/E with written progress reports and test results with recommended actions.
- o. Witness performance testing of all other owner 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 Systems manuals. Examples include smoke control system.
- p. Compile and maintain a commissioning record.
- q. Review O&M manuals submitted by contractors.
- r. Facilitate and verify development and execution of Owner's Training Plan executed by Contractors.
- s. Provide a final commissioning report that includes commissioning plan, specification, Field Reports, Commissioning Meeting Minutes, design reviews, submittal and O&M manual reviews, training plan documents, pre-functional and functional tests, trend log analysis, issues logs, and final test and balance report.

- t. Develop and submit systems manual that include following
    - Sequence of operations for the building;
    - The building occupancy schedule;
    - Equipment run-time schedules;
    - Setpoints for all HVAC equipment;
    - Set lighting levels throughout the building, if available;
    - Minimum outside air requirements;
    - Any changes in schedules or setpoints for different seasons, days of the week, and times of day;
    - Systems narrative describing the mechanical and electrical systems and equipment.
    - Preventive maintenance plan for building equipment described in the systems narrative; and commissioning program that includes periodic commissioning requirements, ongoing commissioning tasks, and continuous tasks for critical facilities
  20. Prepare a standard trend logging package of primary parameters that will provide the operations staff clear indications of system function in order to identify proper system operation and trouble shoot problems. The CA shall also provide any needed information on interpreting the trends.
- F. Owner: Participate in and champion the Commissioning process.
1. *Design Phase*
    - a. Ensure and participate in the development of Owner's Project Requirements (OPR). Review and approve final draft of OPR and any updates during duration of project.
    - b. Review and approve Basis of Design (BOD) by A/E team and any updates
    - c. Review and approve design documents
    - d. Review and approve commissioning plan and schedule
  2. *Construction*
    - a. Review and approve the final Commissioning Plan—Construction Phase.
    - b. Attend a commissioning scoping meeting and other commissioning team meetings.
    - c. Selectively review contractor submittals.
    - d. Furnish a copy of construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CA.
    - e. Review and approve the functional test procedures submitted by the CA, prior to testing.
    - f. Observe and witness startup and performance testing of selected equipment.
    - g. Review commissioning progress and deficiency reports.
    - h. Assist with the resolution of non-compliance and design deficiencies identified in all phases of commissioning.

- i. Assist the GC in coordinating the training of owner personnel.
- j. Provide the BOD documents, prepared by A/E and approved by owner, to the CA and contractor for use in developing the commissioning plan, systems manual, and operation and maintenance training plan.
- k. Assign operation and maintenance personnel and schedule them to participate in commissioning team activities, including testing, training, and O&M document review.

3. *Post Construction Phase*

- a. Assist with coordination and participate in required seasonal or deferred testing and deficiency corrections.
- b. Six to ten months into warranty phase, review with CA the current building operation and the condition of outstanding issues related to the original and seasonal commissioning.

G. Construction Manager (CM), Mechanical/Electrical Coordinator (MEC), and or Test Technician (TT):

1. *Construction Phase*

- a. Facilitate the coordination of the commissioning work by the CA. The CM, TT, and MEC will ensure that commissioning activities are being scheduled into the master schedule.
- b. Attend a commissioning scoping meeting and other commissioning team meetings.
- c. Perform the normal review of Contractor submittals and completed commissioning test results.
- d. When necessary, observe and witness pre-functional checklists, startup, and functional testing of selected equipment.
- e. Review commissioning progress and deficiency reports.
- f. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.
- g. Develop and execute Training Plan to deliver specified systems training to Owner's O&M personnel.
- h. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training.
- i. Prepare and submit As-built documentation for inclusion in the O&M manuals. Assist in coordinating equipment data collection for Dartmouth's computerized maintenance management system (CMMS).
- j. Provide written notice for the completion of the commissioning testing.

2. *Post Construction Phase*

- a. Assist the CA and User Agency as necessary in the seasonal or deferred testing and deficiency corrections required by the specifications.
- b. Ensure that any seasonal or deferred testing and any deficiency issues are addressed.

H. Mechanical, Controls, and TAB Contractors:

The commissioning responsibilities applicable to each of the mechanical, controls, and TAB contractors under 1.05 RELATED WORK A. above is as follows (all references apply to commissioned equipment only):

1. *Construction Phases*

- a. Attend a commissioning scoping meeting and other meetings necessary to facilitate the Commissioning process.
- b. Subcontractors shall provide the CA with normal cut sheets and shop drawing submittals of commissioned equipment.
- c. Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of start-up and functional testing procedures.
  - 1) Typically, this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation, start-up, and checkout materials that are shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Authority.
  - 2) The Commissioning Authority may request further documentation necessary for the commissioning process.
  - 3) This data request may be made prior to normal submittals.
- d. Provide a copy of the O&M manuals and submittals of commissioned equipment, through normal channels, to the CA and A/E for review and approval.
- e. Subcontractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
- f. Provide assistance to the CA in preparing the specific functional performance test procedures. Subs shall review test procedures to ensure feasibility, safety, and equipment protection and provide necessary written alarm limits to be used during the tests.
- g. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the pre-functional checklists from the CA for all commissioned equipment. Submit to CA and A/E for review and approval prior to startup.
- h. During the startup and initial checkout process, execute the mechanical-related portions of the pre-functional checklists for all commissioned equipment.
- i. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA and A/E.
- j. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.
- k. Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving.

- l. Provide skilled technicians to perform functional performance testing under the direction of the CA for specified equipment. Assist the CA in interpreting the monitoring data, as necessary.
- m. Correct deficiencies (differences between specified and observed performance) as interpreted by the CA and A/E and retest the equipment.
- n. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
- o. During construction, maintain as-built drawings.
- p. Provide training of the Owner's operating staff using expert qualified personnel, as specified. Maintain sign-in sheets and provide copies to CA.
- q. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

2. *Post Construction Phase*

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

A. Mechanical Contractor:

The responsibilities of the HVAC mechanical contractor, during Construction Phases in addition to those listed in (A) are:

- 1. Provide startup for all HVAC equipment, except for the building automation control system. Assist in collecting equipment data for Dartmouth's computerized maintenance management system
- 2. Assist and cooperate with the TAB contractor and CA by:
  - a. Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
  - b. Including cost of sheaves and belts that may be required by TAB.
  - c. Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Providing an approved plug.
  - d. Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.
- 3. Install a P/T plug at each water sensor, which is an input point to the control system.
- 4. List and clearly identify on the as-built drawings the locations of all airflow stations.
- 5. Prepare a preliminary schedule for Division 15501 pipe and duct system testing, flushing, and cleaning, equipment start-up and TAB start and completion for use by the CA. Update the schedule as appropriate.
- 6. Notify the CA 48 hours prior to pipe and duct system testing, flushing, cleaning, startup of each piece of equipment and TAB will occur. Be responsible to notify the CM and CA ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed, and that the CA has the scheduling information needed to efficiently execute the commissioning process.

B. Controls Contractor:

The commissioning responsibilities of the controls contractor, during Construction Phases in addition to those listed in (A) are:

1. Sequences of Operation Submittals:

- a. The Controls Contractor's submittals of control drawings shall include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the specifications. They shall include:
  - 1) An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components, and function.
  - 2) All interactions and interlocks with other systems.
  - 3) Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable.
  - 4) Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included but will generally require additional narrative).
  - 5) Start-up sequences.
  - 6) Warm-up mode sequences.
  - 7) Normal operating mode sequences.
  - 8) Unoccupied mode sequences.
  - 9) Shutdown sequences.
  - 10) Capacity control sequences and equipment staging.
  - 11) Temperature and pressure control: setbacks, setups, resets, etc.
  - 12) Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
  - 13) Effects of power or equipment failure with all standby component functions.
  - 14) Sequences for all alarms and emergency shut downs.
  - 15) Seasonal operational differences and recommendations.
  - 16) Initial and recommended values for all adjustable settings, set points and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
  - 17) Schedules, if known.
  - 18) To facilitate referencing in testing procedures, all sequences shall be written in small statements, each with a number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

2. Control Drawings Submittal:

- a. The control drawings shall have a key to all abbreviations.
- b. The control drawings shall contain graphic schematic depictions of the systems and each component.

- c. The schematics will include the system and component layout of any equipment that the control system monitors, enables, or controls, even if the equipment is primarily controlled by packaged or integral controls.
  - d. Provide a full points list with at least the following included for each point:
    - 1) Controlled system
    - 2) Point abbreviation
    - 3) Point description
    - 4) Display unit
    - 5) Control point or set point (Yes / No)
    - 6) Monitoring point (Yes / No)
    - 7) Intermediate point (Yes / No)
    - 8) Calculated point (Yes / No)
  - e. Key:
  - f. Point Description: DB temp, airflow, etc.
  - g. Control or Set point: Point that controls equipment and can have its set point changed (OSA, SAT, etc.)
  - h. Intermediate Point: Point whose value is used to make a calculation which then controls equipment (space temperatures that are averaged to a virtual point to control reset).
  - i. Monitoring Point: Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification.
  - j. Calculated Point: “Virtual” point generated from calculations of other point values.
- 3. The Controls Contractor shall keep the CA and A/E informed of all changes to this list during programming and setup.
  - 4. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.
  - 5. Assist and cooperate with the TAB contractor in the following manner:
    - a. Meet with the TAB contractor prior to beginning TAB and review the TAB plan to determine the capabilities of the control system toward completing TAB. Provide the TAB any needed unique instruments for setting terminal unit boxes and instruct TAB in their use (handheld control system interface for use around the building during TAB, etc.).
    - b. For a given area, have all required prefunctional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CA prior to TAB.
    - c. Provide a qualified technician to operate the controls to assist the TAB contractor in performing TAB, or provide sufficient training for TAB to operate the system without assistance.
  - 6. Assist and cooperate with the CA in the following manner:
    - a. Using a skilled technician who is familiar with this building, execute the functional testing of the controls system as specified for the controls contractor.

- Assist in the functional testing of all equipment specified. Provide two-way radios during the testing.
    - b. Execute and provide all control system trend logs, screen capture pictures requested to demonstrate the equipment /system is functioning per control sequences and design intent.
  - 7. The controls contractor shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to functional performance testing. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:
    - a. System name.
    - b. List of devices.
    - c. Step-by-step procedures for testing each controller after installation, including:
      - 1) Process of verifying proper hardware and wiring installation.
      - 2) Process of downloading programs to local controllers and verifying that they are addressed correctly.
      - 3) Process of performing operational checks of each controlled component.
      - 4) Plan and process for calibrating valve and damper actuators and all sensors.
      - 5) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
    - d. A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor or controller has “passed” and is operating within the contract parameters.
    - e. A description of the instrumentation required for testing.
    - f. Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CA and TAB contractor for this determination.
  - 8. Provide a signed and dated certification to the CA and A/E upon completion of the checkout of each controlled device, equipment and system prior to functional testing for each piece of equipment or system, that all system programming is complete as to all respects of the Contract Documents, except functional testing requirements.
  - 9. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as requested by the CA to demonstrate system operation.
  - 10. List and clearly identify on the as-built duct and piping drawings the locations of all static and differential pressure sensors (air, water and building pressure).
- C. TAB Contractor: The duties of the TAB contractor, in addition to those listed:
- 1. Six weeks prior to starting TAB, submit to the CA and A/E the qualifications of the site technician for the project.

2. Submit the outline of the TAB plan and approach for each system and component to the CA, A/E, and the controls contractor six weeks prior to starting the TAB.  
This plan will be developed after the TAB has some familiarity with the control system.
3. The submitted plan will include:
  - a. Certification that the TAB contractor has reviewed the construction documents and the systems with the design engineers and contractors to sufficiently understand the design intent for each system.
  - b. An explanation of the intended use of the building control system. The controls contractor will comment on feasibility of the plan.
  - c. All field checkout sheets and logs to be used that list each piece of equipment to be tested, adjusted and balanced with the data cells to be gathered for each.
  - d. Discussion of what notations and markings will be made on the duct and piping drawings during the process.
  - e. Final test report forms to be used.
  - f. Detailed step-by-step procedures for TAB work for each system and issue: terminal flow calibration (for each terminal type), diffuser proportioning, branch / submain proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions, etc. Criteria for using air flow straighteners or relocating flow stations and sensors will be discussed. Provide the analogous explanations for the waterside.
  - g. List of all airflow, water flow, sound level, system capacity and efficiency measurements to be performed and a description of specific test procedures, parameters, formulas to be used.
  - h. Details of how *total* flow will be determined (Air: sum of terminal flows via BAS calibrated readings or via hood readings of all terminals, supply (SA) and return air (RA) pitot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic, etc.).
  - i. The identification and types of measurement instruments to be used and their most recent calibration date.
  - j. Specific procedures that will ensure that both air and water side are operating at the lowest possible pressures and provide methods to verify this.
  - k. Confirmation that TAB understands the outside air ventilation criteria under all conditions.
  - l. Details of whether and how minimum outside air cfm will be verified and set, and for what level (total building, zone, etc.).
  - m. Details of how building static and exhaust fan / relief damper capacity will be checked.
  - n. Proposed selection points for sound measurements and sound measurement methods.
  - o. Details of methods for making any specified coil or other system plant capacity measurements.
  - p. Details of any TAB work to be done in phases (by floor, etc.), or of areas to be built out later.
  - q. Details regarding specified deferred or seasonal TAB work.
  - r. Details of any specified false loading of systems to complete TAB work.
  - s. Details of all exhaust fan balancing and capacity verifications, including any required room pressure differentials.
  - t. Details of any required interstitial cavity differential pressure measurements and calculations.

- u. Plan for hand-written field technician logs of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests (scope and frequency).
  - v. Plan for formal progress reports (scope and frequency).
  - w. Plan for formal deficiency reports (scope, frequency and distribution).
4. A running log of events and issues shall be kept by the TAB field technicians. Submit hand-written reports of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests to the CA and CM at least twice a week.
  5. Communicate in writing to the controls contractor all set point and parameter changes made or problems and discrepancies identified during TAB which affect the control system setup and operation.
  6. Provide a draft TAB report within two weeks of completion. A copy will be provided to the CA and A/E. The report will contain a full explanation of the methodology, assumptions and the results in a clear format with designations of all uncommon abbreviations and column headings. The report should follow the latest and most rigorous reporting recommendations by AABC, NEBB or ASHRAE Standard 111.
  7. Provide the CA and A/E with any requested data, gathered, but not shown on the draft reports.
  8. Provide a final TAB report for the CA and A/E with details, as in the draft.
  9. Conduct functional performance tests and checks on the original TAB as specified.
- D. Electrical Contractors: The commissioning responsibilities applicable to the electrical contractor are as follows *(all references apply to commissioned equipment only)*:

1. *Construction Phases*

- a. Include the cost of commissioning in the contract price, if not yet let.
  - b. In each purchase order or subcontract written, include requirements for submittal data, O&M data and training.
  - c. Attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the Commissioning process.
  - d. Contractors shall provide normal cut sheets and shop drawing submittals to the CA of commissioned equipment.
  - e. Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of start-up and functional testing procedures.
- 1) Typically, this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Authority.
  - 2) The Commissioning Authority may request further documentation necessary for the commissioning process.
  - 3) This data request may be made prior to normal submittals.

- f. Provide a copy of the O&M manuals submittals of commissioned equipment, through normal channels, to the CA for review and approval.
- g. Subcontractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
- h. Provide assistance to the CA in preparation of the specific functional performance test procedures. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
- i. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the pre-functional checklists from the CA. Submit manufacturer's detailed start-up procedures and the full start-up plan and procedures and other requested equipment documentation to CA for review. Assist in collecting equipment data for Dartmouth's computerized maintenance management system.
- j. During the startup and initial checkout process, execute and document the electrical-related portions of the pre-functional checklists provided by the CA for all commissioned equipment.
- k. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA and A/E.
- l. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.
- m. Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
- n. Perform functional performance testing under the direction of the CA for specified equipment. Assist the CA in interpreting the monitoring data, as necessary.
- o. Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, and A/E and retest the equipment.
- p. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
- q. During construction, maintain as-built drawings and prepare final as-built drawings at project completion.
- r. Provide training of the Owner's operating personnel as specified.
- s. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

1. *Post Construction Phase*

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

**3.2 SYSTEMS TO BE COMMISSIONED**

((SAMPLE: to be modified to suit project conditions))

**A. HVAC**

1. Each exhaust fans.
2. Each supply fans.
3. Each return fans.
4. Each Package DX split system air condition or heat pump
5. Each air handling unit.
6. Each Heat exchanger.
7. Each pump set and system.
8. Each air flow station.
9. Each VSD.
10. Fuel oil gauge and alarm system.
11. Cabinet unit heaters and unit heaters.
12. Each differential pressure valves.
13. Each Terminal DDC terminal box/ unit.
14. Cooling System (chiller, tower, condensing unit and associate pump)
15. Glycol Feeder system
16. Steam system (PRV and Condensate receivers).
17. Where pneumatic systems are installed, verify actual compressor run time versus the calculated run time.
18. Building Automation System (sensor & control points, actuators, flow stations and program sequences)
19. Air pressure in expansion tanks shall be measured and compared with specs. And the pressure reducing valve setting.

**B. Plumbing**

1. Rain water collection systems (included)
2. Sump pump
3. Domestic hot water heater system.

- C. Electrical
  - 1. Generator, Automatic Transfer Switch, Annunciator and other control interfaces.
  - 2. Short Circuit Trip (review only)
  - 3. Circuit breakers: verify trip settings.
  - 4. Fire Alarm System including interface to HVAC/ATC.
  - 5. Battery powered Emergency and Exit Lights. Buildings with battery powered emergency and exit lights, the system shall be subjected to the 1.5-hour test.
  - 6. Emergency Lighting Devices and/or System Operation
  - 7. Addressable Smoke Detectors. Buildings with addressable fire alarm systems shall have all smoke detectors tested for cleanliness. The minimum acceptable parameter is level 9 (out of a possible 10). If the commissioning Authority does not have the equipment to perform this test, Dartmouth College can perform the test in conjunction with the on-site Authority.
  - 8. Variable Frequency Drives. Systems equipped with variable frequency drives shall be tested when the drive is engaged as well as in the bypass mode.
  - 9. Lighting Control Systems/Panels
  - 10. Lighting Control Devices (includes occupancy sensors, photocells and timers, dimmers, contactors, User controls, GUI's, daylight sensors, gateways, fixtures control devices,)
  - 11. Access Control Systems
  - 12. Renewable Energy Systems (if included)
  - 13. Egress pressurization Systems (if included)
  - 14. Uninterruptable Power Supplies (UPS)
  - 15. Arc Flash Hazard labelling
  - 16. Meters – include verification of configuration to campus energy monitoring servers-software and to campus power monitoring server-software.

PLUMBING ((SAMPLE: to be modified to suit project conditions))

### 3.3 SUMP PUMP AND RAIN WATER COLLECTION TANKS

- A. Parties Responsible to Execute Functional Test:
  - 1. Electrical Contractor
  - 2. Plumbing Contractor: Operate the controls to activate the equipment.
  - 3. CA: To witness and document testing.
  - 4. Manufacturer's Representative.
- B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.
  - 1. Float switch settings
  - 2. Minimum run timer
  - 3. High water alarm
- C. Prerequisites:
  - 1. The applicable prerequisite checklist items listed in Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations

on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions/Modes Required To Be Tested, Test Methods:

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both <sup>1</sup>	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Verify set points and run times to be reasonable and appropriate.		
3. Verify operation and activation of high water alarm at all locations.	Manual	

<sup>1</sup>Refer to Special Procedures

- E. Special Procedures (other equipment to test with, etc.; reference to function ID): None
- F. Sampling Strategy: Test all units.

END OF SUMP PUMP AND RAIN WATER COLLECTION TANKS

### 3.4 PLUMBING WATER SYSTEM

A. Parties Responsible to Execute Functional Test

1. CA: witness and document testing.
2. Plumbing Contractor to make all adjustments.

B. Integral Components or Related Equipment Being Tested

1. This procedure applies to the following systems:
  - a. Hot and Cold Domestic Water Systems
  - b. Hot and Cold Non-Potable Water Systems
2. Hot water heaters (heaters, mixing valves)
3. Recirculating pumps

- C. Prerequisites: The applicable prerequisite checklist items shall be checked off prior to functional testing. The commissioning Authority may also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

- D. Functions/Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

Function/Mode	Test Method
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual
2. Verify schedules and set points to be reasonable and appropriate	
3. Mixing valve operation and temperature control	Either
4. Sensor calibration checks on hot water temperature	Manual

- E. Special Procedures (other equipment to test with, etc.; reference to function ID)

1. None

- F. Required Monitoring

1. None

- G. Acceptance Criteria (Referenced by function or mode ID)

1. For the conditions, sequences and modes tested, equipment responds to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

- H. Sampling Strategy for Identical Units

1. No sampling. Test all units.

### END OF PLUMBING WATER SYSTEM

MECHANICAL ((SAMPLE: to be modified to suit project conditions))

## 3.5 HOT WATER HEATING SYSTEM (HEAT EXCHANGERS/HX, PUMPS, DISTRIBUTION)

- A. Parties Responsible to Execute Functional Test:

1. Vendor Support Representative
2. Controls Contractor: Operate the controls, as needed
3. HVAC mechanical contractor or vendor: Assist in testing sequences
4. CA: To witness and document testing

- B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.

1. HX
2. HW pumps
3. HW pump VFDs
4. Burner and blower
5. Pressurized compression tank and air separation
6. Water treatment and water makeup systems

C. Prerequisites:

1. The applicable prerequisite checklist items listed in Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions/Modes Required To Be Tested, Test Methods and Seasonal Test Requirements.

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u> <sup>1</sup>
General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Supply pump staging, bypass valve operation, if no VFD and HWT reset. VFD operation: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, verification of program settings, alarms, etc.	Both	Heating
3. Check all alarms and safeties (high and low pressure and temperature, etc.), PRV and flow switch functions	Manual	
4. Test each possible lead boiler as lead boiler, and each pump as lead pump. Test pump lockouts.	Manual	
5. Verify boiler inlet/outlet pressures with startup report and manufacturer's recommendations.	Manual	
6. Sensor and actuator calibration checks on: HWST, HWRT, pressure sensor controlling pump speed, mixing valve and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of the pressure set point, with a test gage).	Manual	
7. Constancy of differential pressure (pump control parameter)	Monitoring	Heating

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test<sup>1</sup></u>
8. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Post Construction Phase is complete.	Monitoring	Both
9. Burner operation and controls, fuel gas pilot, flow and pressure, flue gases and barometric dampers outlet temperature emission controls.		
10. Water treatment, water levels, pressure and temperature safeties and alarms.		
11. Verify schedules and set points to be reasonable and appropriate		

E. Special Procedures (other equipment to test with, etc.; reference to function ID):

1. False load HX, if necessary.
2. Testing of PRVs.
3. Condensate receiver pump tests.

F. Acceptance Criteria (referenced by function or mode ID):

1. For the conditions, sequences, and modes tested, the HX, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
2. HX controls shall maintain the supply water set point to within +/- 3.0F of set point dead band without excessive hunting.
3. Pumping system and controls shall maintain the current desired pressure set point to within an amount equal to 10% of the set point value either side of the dead band without excessive hunting.

G. Sampling Strategy for Identical Units: No sampling, test all.

## END OF HOT WATER HEATING SYSTEM (HEAT EXCHANGERS, PUMPS, DISTRIBUTION)

### 3.6 TERMINAL UNITS (FCU, FPT, VAV, CUH, UH)

(This applies to standard applications; critical applications will have additional tests and a higher fraction tested.)

A. Parties Responsible to Execute Functional Test:

1. Controls Contractor: Operate the controls to activate the equipment.
2. CA to record results.

3. Mechanical Contractor to make any adjustments.
- B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.
1. VAV Boxes w/ and w/o Reheat Coils
  2. Radiation
  3. Unit Heaters
  4. Air Handling Systems
- C. Prerequisites:
1. The applicable prerequisite checklist items listed in the Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.
- D. Functions/Modes Required To Be Tested, Test Methods:
1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both <sup>2</sup>	<u>Required</u> <u>Seasonal</u> <u>Test</u> <sup>1</sup>
General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, warm-up, shutdown, unoccupied & manual modes and power failure and restoration. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with, including all damper, valve and fan functions.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Sensor activator calibration checks on: SAT, zone air temperature damper position and other random checks (EMS readout against visual or hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure set point, with an inclined manometer)	Manual	
3. Device and actuator calibration and stroke checks for heating coil valve and dampers	Manual	
4. For the TU's tested, check the prefunctional checklist items.	Observation	
5. Verify control parameters and set points to be reasonable and appropriate by reviewing the full program of 5% of all the TU's with each other for consistency. Verify the max. and min. cfm set points of all tested TU's against the control drawing and TAB	Observation	

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both <sup>2</sup>	<u>Required</u> <u>Seasonal</u> <u>Test</u> <sup>1</sup>
values. Verify other TU programming parameters such as K-factors, dead bands, set points, stroke times, etc.		
6. Verify proper operation of valve in both cooling and heating modes under occupied and unoccupied conditions.	Both	Both
7. Verify no hunting or significant overshoot by valves and dampers.	Either	
8. Verify by measurement, CCV & HCV positive shutoff (no leak-thru)	Manual	
9. All alarms (fan status, low limits, etc.)	Manual	
10. Verify that TU is maintaining space set point temperatures and fans are being cycled as specified	Monitoring	Both Design
11. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Post Construction Phase is complete.	Monitoring	Both

E. Special Procedures (other equipment to test with, etc.; reference to function ID): None

F. Acceptance Criteria (referenced by function or mode ID):

1. For the conditions, sequences and modes tested, the TU, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
2. Space temperature during occupied modes shall average within +/- 1°F of set point and always remain within 1°F of the ends of the dead band without excessive hunting of the coil valve or complaints of drafts or stuffiness from occupants.

G. Sampling Strategy for Identical:

1. Units of the same type and function, but different in size, are considered identical for sampling purposes.
2. Testing:
  - a. Randomly test at least 25% of each group of identical equipment (the 1st sample). In no case test less than three units in each group. If 10% of the units in the first sample fail the functional performance tests, test another 10% of the group (the 2nd sample). If 10% of the units in the 2nd sample fail, test all remaining units in the whole group, fully at the contractor's expense. This sampling applies to the testing subsections. That is, if calibration is off on more than 10% of the tested piece of equipment, then another sample shall have calibrations checked, but not all other tests need to be done on the second sample.
3. Monitoring:

- a. Twenty five percent of the total number of zones in the building, chosen by the Owner, shall be monitored. Within this 25%, shall be included a distribution of all air handlers, zones expected to have the greatest heating and cooling demand, perimeter and core zones and zones identified from the commissioning process that have exhibited potential problems.

#### END OF TERMINAL UNITS (FCU, FPT, VAV, CUH, UH)

### 3.7 PACKAGED DX SPLIT SYSTEM AIR CONDITIONING OR HEAT PUMP

#### A. Parties Responsible to Execute Functional Test:

1. Controls Contractor: Operate the controls to activate the equipment.
2. CA: To witness and document testing.
3. TAB Contractor to verify airflows.
4. Unit Manufacturer's Representative.

#### B. Integral Components or Related Equipment Being Tested:

1. Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.
  - a. Unit (fans, coils, condenser, compressors, ducts, VFD)

#### C. Prerequisites:

1. The applicable prerequisite checklist items listed in the Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

#### D. Functions/Modes Required To Be Tested, Test Methods:

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both <sup>2</sup>	<u>Required</u> <u>Seasonal</u> <u>Test</u> <sup>1</sup>
General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both <sup>2</sup>	<u>Required</u> <u>Seasonal</u> <u>Test</u> <sup>1</sup>
2. Supply air, and reset temp. control functions	Both	
3. SF, RF and exhaust fan interlocks	Either	
4. Compressor unloading & condenser fan staging for head pressure control	Both	
5. Damper interlocks and correct modulation in all modes, including fire and smoke dampers	Manual	
6. Temperature difference across cooling coils	Manual	
7. Verify TAB reported SF cfm with control system reading	Manual	
8. All alarms (low limits, high static, freezestat, etc.)	Manual	
9. Unit cooling capacity tests	Manual	Design
10. Sensor and actuator calibration checks on: SAT, RAT, and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure set point, with an inclined manometer)	Manual	
11. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Post Construction Phase is complete.	Monitoring	Both
12. Verify control strategies, schedules and set points to be reasonable and appropriate		

E. Special Procedures (other equipment to test with, etc.; reference to function ID): None

F. Acceptance Criteria (referenced by function or mode ID):

1. For the conditions, sequences and modes tested, the system, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

G. Sampling Strategy: Test all units.

#### **END OF PACKAGED DX SPLIT SYSTEM AIR CONDITIONING OR HEAT PUMP**

### **3.8 EXHAUST FANS**

A. Parties Responsible to Execute Functional Test

1. Controls Contractor: Operate the controls to activate the equipment.
2. CA: To witness and document testing.
3. TAB Contractor to verify airflows.
4. Mechanical Contractor to make any adjustments.

B. Integral Components or Related Equipment Being Tested: Prefunctional checklists must be complete for all of the components listed below prior to performing this functional test.

1. Controls

## 2. Terminal equipment

- C. Prerequisites The applicable prerequisite checklist items shall be signed off prior to functional testing. The commissioning Authority may spot-check misc. items and calibrations on the prefunctional checklists before the beginning of functional testing.

- D. Functions/Modes Required To Be Tested, Test Methods:

Function/Mode	Test Method	Seasonal Test
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shut-down, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
2. Verify schedules and set points to be reasonable and appropriate		
3. Function at fire alarm (off, depressurization, etc.)	Manual	
4. Check TAB report record of sound power level tests and space pressures and compare to specifications	Review	
5. Sensor calibration checks on any controlling temperature or pressure sensor	Manual	

- E. Special Procedures (other equipment to test with, etc.; reference to function ID)

1. None.

- F. Acceptance Criteria (referenced by function or mode ID)

1. For the conditions, sequences and modes tested, the fans, integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

**END OF EXHAUST FANS****3.9 BUILDING AUTOMATION SYSTEM (BAS)**

- A. Parties Responsible to Execute Functional Test:

- Controls Contractor: Operate the controls to activate the equipment.
- CA: To witness and document testing.

- B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.

- Building Automation System
- All prefunctional checklists of controlled equipment

## C. Prerequisites:

1. The applicable prerequisite checklist items listed in the Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

## D. A significant part of the BAS functional testing requirements is the successful completion of the functional tests of equipment the BAS controls or interlocks with. Uncompleted equipment functional tests or outstanding deficiencies in those tests lend the required BAS functional testing incomplete.

## E. Integral or stand-alone controls are functionally tested with the equipment they are attached to, including any interlocks with other equipment or systems and thus are not covered under the BAS testing requirements, except for any integrated functions or interlocks listed below.

## F. In addition to the controlled equipment testing, the following tests are required for the BAS, where features have been specified. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in the specifications.

<u>Function/Mode</u>	<u>Test Method</u> Manual (demonstration), Monitoring, Either or Both
<b>MISC. FUNCTIONS</b>	
1. All specified functions and features are set up, debugged and fully operable	Verbal discussion of features
2. Power failure and battery backup and power-up restart functions	Demonstration
3. Specified trending and graphing features demonstration	See equipment trends
4. Global commands features	Demonstration
5. Security and access codes	Demonstration
6. Occupant over-rides (manual, telephone, key, keypad, etc.)	Demonstration
7. O&M schedules and alarms	Demonstration
8. Scheduling features fully functional and setup, including holidays	Observation in terminal screens or printouts
9. Included features not specified to be setup are installed (list)	Demonstration
10. Demonstrate functionality of field panels using local operator keypads and local ports (plug-ins) using portable computer/keypad	Demonstration of 100% of panels and 10% of ports
11. All graphic screens and value readouts completed	Demonstration
12. Set point changing features and functions	Done during equipment testing
13. Communications to remote sites	Demonstration
14. Sensor calibrations	Sampled during equipment tests
15. Final as-builts or redlines (per spec) control drawings, final points list, program code, set points, schedules, warranties, etc. per specs, submitted for O&Ms.	Observation

<u>Function/Mode</u>	<u>Test Method</u> Manual (demonstration), Monitoring, Either or Both
16. Verify that points that are monitored only, having no control function, are checked for proper reporting to BAS.	Observation
17. Optional Start/Stop Routine.	
18. Final room numbers programmed into system.	
19. Worcester standard point naming conventions used.	
<b>INTEGRATED TESTS</b>	
20. Fire alarm interlocks and response	Demonstration
21. Demand limiting (including over-ride of limiting)	Monitoring
22. Sequential staging ON of equipment	Either
23. All control strategies and sequences not tested during controlled equipment testing	Either
24. Other integrated tests specified in the contract documents	
25. Emergency power operation and return to normal power.	
26. Fire protection and suppression systems	Demonstration

G. Special Procedures (other equipment to test with, etc.; reference to function ID): None

H. Acceptance Criteria (referenced by function or mode ID):

1. For the conditions, sequences and modes tested, the BAS, integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

#### **END OF BUILDING AUTOMATION SYSTEM (BAS)**

### **3.10 TEST AND BALANCE WORK (TAB)**

A. Parties Responsible to Execute Functional Test:

1. TAB Contractor: Perform checks using test instruments.
2. Controls Contractor: Operate the controls to activate the equipment.
3. CA: To witness and document testing.

B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.

1. TAB water-side
2. TAB air-side
3. TAB equipment and systems
4. TAB electrical

## C. Prerequisites

1. The applicable prerequisite checklist items listed in the beginning of this Section shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer, before the beginning of functional testing.

## D. Purpose:

1. The purpose of this test is to spot check the TAB work to verify that it was done in accordance with the contract documents and acceptable practice and that the TAB report is accurate.

- E. The following tests and checks will be conducted. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Test or Check</u>	<u>Test Method</u>	<u>Required Seasonal Test<sup>3</sup></u>
<p>1 A random sample of up to 5 % the TAB report data shall be selected for verification (air velocity, air or water flow rate, pressure differential, electrical or sound measurement, etc.). The original TAB contractor will execute the checks, witnessed by the commissioning authority. The TAB contractor will use the same test instruments as used in the original TAB work.</p> <p>A failure<sup>1</sup> of more than 10% of the selected items of a given system<sup>2</sup> shall result in the failure of acceptance of the system TAB report and the TAB contractor shall be responsible to rebalance the system, provide a new system TAB report and repeat random verifications of the new TAB report.</p> <p>The random testing will include the verification of minimum outdoor air intake flows at minimum, maximum and intermediate total airflow rates for 100% of the air handlers. Other selected data to be verified will be made known upon day of testing.</p>	Demonstration	
2 Verify that final settings of all valves, splitters, dampers and other adjustment devices have been permanently marked by the TAB Contractor.	Demonstration	
3 Verification that the air system is being controlled to the lowest possible static pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control set points established by TAB and a physical verification of at least one leg from fan to diffuser having all balancing dampers wide open and that during full cooling of all TUs taking off downstream of the static pressure sensor, the TU on the critical leg has its damper 90% or more open.	Demonstration	
4 Verification that the water system is being controlled to the lowest possible pressure while still meeting design loads, less diversity.	Demonstration	

<u>Test or Check</u>	<u>Test Method</u>	<u>Required Seasonal Test<sup>3</sup></u>
This shall include a review of TAB methods, control set points established by TAB and a physical verification of at least one leg from the pump to the coil having all balancing valves wide open and that during full cooling the cooling coil valve of that leg is 90% or more open.		

<sup>1</sup>Failure of an item is defined as follows:

- For airflow of supply and return: a deviation of more than 10% of instrument reading
- For minimum outside airflow: 20% of instrument reading (30% for reading at intermediate supply flow for inlet vane or VFD OSA compensation system using linear proportional control)
- For temperatures: a deviation of more than 1°F
- For air and water pressures: a deviation of more than 10% of full scale of test instrument reading
- For sound pressures: a deviation of more than 3 decibels. (Variations in background noise must be considered)

<sup>2</sup>Examples of a “system” are: the air distribution system served by one air handler or the hydronic hot water supply system served by a boiler. Systems can be defined smaller if inaccuracies in TAB work within the smaller defined system will have little or no impact on connected systems.

<sup>3</sup>Cooling season, Heating season or Both. “Design” means within 5° of season design (ASHRAE 2 1/2°), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

- F. Special Procedures (other equipment to test with, etc.; reference to function ID): None
- G. Required Monitoring: None
- H. Acceptance Criteria (referenced by function or mode ID): Provided in footnote to test table above.
- I. Sampling Strategy for Identical Units: Described in test table above.

### END OF TEST AND BALANCE WORK (TAB)

## 3.11 AIR HANDLING UNITS (RECIRCULATING AND 100% O.A.)

- A. Parties Responsible to Execute Functional Test
  - 1. Controls Contractor: Operate the controls to activate the equipment.
  - 2. CA: To witness and document testing.
  - 3. TAB Contractor to verify air and water flows.
  - 4. Mechanical Contractor to fix any problems.
  - 5. Unit Manufacturer's Representative.
- B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.
  - 1. Chilled Water System to cooling section
  - 2. Hot water heating system or gas to unit heating section

## C. Prerequisites:

1. The applicable prerequisite checklist items listed in the Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

## D. Functions/Modes Required To Be Tested, Test Methods:

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both <sup>2</sup>	<u>Required</u> <u>Seasonal</u> <u>Test</u> <sup>1</sup>
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Hot water coil and face and bypass dampers temperature control functions	Both	Heating
3. Economizer functions	Both	Cooling
4. SF, RF and exhaust fan interlocks	Either	
5. Damper interlocks and correct modulation in all modes, including fire and smoke dampers and CO <sub>2</sub> control	Manual	
6. Temperature difference across heating and cooling coils	Manual	Both
7. Smoke detectors and smoke evac control from fire alarm control panel.	Manual	
8. Verify TAB reported SF and RF cfm with control system reading	Manual	
9. All alarms (low limits, high static, freezestat, etc.)	Manual	
10. Supply and return fans static pressure and volume matching control	Monitoring	Design
11. Sensor and actuator calibration checks on: SAT, MAT, OSAT, CO <sub>2</sub> , economizer and RA dampers and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure set point, with an inclined manometer)	Manual	
12. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Acceptance Phase is complete. Provide CA with all requested data until approved.	Monitoring	Both
13. Verify control strategies, schedules and set points to be reasonable and appropriate		

- E. Special Procedures (other equipment to test with, etc.; reference to function ID): None
- F. Acceptance Criteria (referenced by function or mode ID):
  - 1. For the conditions, sequences and modes tested, the system, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
- G. Sampling Strategy: Test all units.

### END OF AIR HANDLING UNITS (RECIRCULATING AND 100% O.A.)

ELECTRICAL ((SAMPLE: to be modified to suit project conditions))

### 3.12 EMERGENCY GENERATOR

- A. Parties Responsible to Execute Functional Test
  - 1. Vendor Support Representative
  - 2. Electrical Contractor
  - 3. CA: To witness and document testing
- B. Integral Components or Related Equipment Being Tested: Prefunctional Test Complete?
  - 1. Generator Motor
  - 2. Generator Cooling System
  - 3. Generator Fuel System and Leak Detection System
  - 4. Phase Rotation
- C. Prerequisites:
  - 1. The applicable prerequisite checklist items listed in the Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.
- D. Functions/Modes Required To Be Tested, Test Methods:
  - 1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u> <sup>1</sup>
General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup,	Manual	Both

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required Seasonal Test<sup>1</sup></u>
shutdown, remote annunciation. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.		
2. Stimulate power outage and subsequent automatic transfer switch operation(s)	Manual	
3. Generator start capability upon signal from ATS upon loss of utility power	Manual	
4. Check all alarms and annunciators local and remote and remote	Manual	
5. Demonstrate interior of enclosure operational, i.e., lighting, battery chargers, etc.	Manual	
6. Demonstrate proper functioning of governor and regulator	Manual	
7. Verify operation of all mechanical equipment elevators and fire pump from generator power and restart upon re-energizing normal power.		

<sup>1</sup>Cooling season, Heating season or Both. “Design” means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

E. Acceptance Criteria (referenced by function or mode ID):

1. For the conditions, sequences and modes tested, the generator, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

### END OF EMERGENCY GENERATOR

### 3.13 EMERGENCY LIGHTING

A. Parties Responsible to Execute Functional Test:

1. Electrical Contractor
2. CA: To witness and document testing

B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.

1. Emergency Lighting Fixtures
2. Emergency lighting illumination levels, including exterior.
3. Emergency Bypass Relays
4. Function of emergency lighting mode (on loss of normal power or fire alarm activation) of lighting control system.
5. Emergency lighting battery units.

## C. Prerequisites:

1. The applicable prerequisite checklist items listed in Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

## D. Functions/Modes Required To Be Tested, Test Methods:

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General		
1. Test all manual controls individually.	Manual	
2. Demonstrate all automatic functions using manual control overrides.		
3. Demonstrate all interlocking functions, i.e., security/fire alarm.		

## E. Acceptance Criteria

1. Acceptance is achieved when all functions of the specified system have been demonstrated.

## F. Sample strategy for identical units: No sampling, test all.

**END OF EMERGENCY LIGHTING****3.14 SHORT CIRCUIT TRIP**

## A. Parties Responsible to Execute Functional Test:

1. Electrical Contractor, Manufacturer's start-up
2. Third Party Testing for primary injection test of mains (above 600A), and secondary injection testing of all feeders (above 100A)
3. CA: To witness and document testing

## B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.

1. Breaker trip settings for all adjustable trip type breakers

## C. Prerequisites:

1. The applicable prerequisite checklist items listed in Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

## D. Functions/Modes Required To Be Tested, Test Methods:

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General		
1. Review breaker settings per the short circuit protection study.	Manual	

## E. Acceptance Criteria (referenced by function or mode ID):

1. System is in compliance when trip settings are observed to be coordinated with report recommendations.

F. Sampling strategy for identical units: No sampling, test all.

G. Add – checking arc flash hazard labels

**END OF SHORT CIRCUIT TRIP****3.15 LIGHTING CONTROL SYSTEM**

## A. Parties Responsible to Execute Functional Test:

1. Vendor Support Representative
2. Electrical Contractor
3. CA: To witness and document testing

## B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.

1. Head end system (PC or Cloud)
2. Relay panels, Dimming panels, Node/Room control panels, Gateways
3. Occupancy/Vacancy sensors,
4. Low voltage, wireless, 0-10V, etc. user controls and GUIs
5. Light control devices
6. Daylight sensors and override
7. AV interface

8. Fire Alarm interface device
9. Demand Response input
10. System software

C. Prerequisites:

1. The applicable prerequisite checklist items listed in Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions/Modes Required To Be Tested, Test Methods:

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General 1. Demonstrate all functions of the lighting control/low voltage/wireless control system and head end equipment	Manual	

E. Acceptance Criteria (referenced by function or mode ID):

1. Acceptance is achieved when all lighting functions are successfully demonstrated.

F. Sampling Strategy for Identical Units: No sampling, test all.

### END OF LIGHTING CONTROL SYSTEM

## 3.16 AUTOMATIC TRANSFER SWITCH(ES)

A. Parties Responsible to Execute Functional Test:

1. Vendor Support Representative
2. Electrical Contractor
3. Building Inspector
4. CA: To witness and document testing
- 5.

B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.

1. Manual and automatic operation

2. Function annunciation
  3. Remote monitoring and/or remote control operation
- C. Prerequisites:
1. The applicable prerequisite checklist items listed in Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.
- D. Functions/Modes Required To Be Tested, Test Methods:
1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General		
1. Verify installation of switch.	Manual	
2. Demonstrate compliance with electrical sequence of operation.		

- E. Acceptance Criteria
1. Acceptance is achieved when all functions of the specified system have been demonstrated.
- F. Sample strategy for identical units: No sampling, test all.

### END OF AUTOMATIC TRANSFER SWITCH(ES)

## 3.17 RENEWABLE ENERGY SYSTEM

- A. Parties Responsible to Execute Functional Test:
1. Vendor Support Representative
  2. Electrical Contractor
  3. CA: To witness and document testing
- B. Integral Components or Related Equipment Being Tested: Prefunctional tests must be complete for all of the components listed below prior to performing this functional test.
1. PV array
  2. Static inverters
  3. Charge controllers

4. Metering
5. Bypass diodes
6. Data acquisition system (DAS)
7. Rapid Shutdown Control

C. Prerequisites:

1. The applicable prerequisite checklist items listed in Part 1 of this section and paragraph B above shall be listed on each functional test form and checked off prior to functional testing. The commissioning Authority will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions/Modes Required To Be Tested, Test Methods:

1. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Specification.

<u>Function/Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General 1. Demonstrate all functions of the renewable energy system according to manufacturer's instructions.	Manual	

E. Sampling Strategy for Identical Units: No sampling, test all.

**END OF RENEWABLE ENERGY SYSTEMS**

**END OF SECTION 01 91 13**