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ADDENDUM #5

Date: 23 March 2006

To: Contractors

From: Matthias Mueller, DFCM – Project Manager

Reference: Division of Facilities Construction and Management Construction Services for Old Main Building Remodel & Seismic Upgrade and CMGC Services for New Teacher Education Building DFCM Project Nos. 03234730 and 05049730

Subject: **Addendum No. 5**

Pages	Cover Page	1 page
	Revised Schedule	66 page
	Total	67 pages

Note: This Addendum shall be included as part of the Contract Documents. Items in this Addendum apply to all drawings and specification sections whether referenced or not involving the portion of the work added, deleted, modified, or otherwise addressed in the Addendum. Acknowledge receipt of this Addendum in the space provided on the Bid Form. Failure to do so may subject the Bidder to disqualification.

5.1 Project Manual

Add the following attached commissioning specification sections to the Project Manual: 01140, 01300, 01701, 01730, 15010, 15950, 15991, 15995, 15997, 16010, 16995, 16997, and 17100.

SECTION 01140 – COORDINATION COMMISSIONING AGENT – GENERAL REQUIREMENTS

1.1 COMMISSIONING

- A. This project will have selected building systems commissioned. The equipment and systems to be commissioned are specified in Section 17100 Part 1.7. The commissioning process, which the Contractor is responsible to execute, is defined in Division 17100 Part 1.3. A Commissioning Authority whose services will be provided by the Owner will direct the commissioning process.
- B. Abbreviations. The following are common abbreviations used in the *Specifications* and in the *Commissioning Plan*. Definitions are found in Section 17100 Part 1.6.

A/E -	Architect and Design Engineers	FT -	Functional Performance Test
CxA -	Commissioning Authority	GC -	General Contractor (prime)
CC -	Controls Contractor	MC -	Mechanical Contractor
CM -	Construction Manager (the Owner's Representative)	PC -	Pre-Functional Checklist
Cx -	Commissioning	PM -	Project Manager
Cx Plan -	Commissioning Plan Document	Subs -	Subcontractors
EC -	Electrical Contractor	TAB -	Test and Balance Contractor

1.2 ADMINISTRATIVE / SUPERVISORY PERSONNEL

- A. Commissioning Authority. The Owner will provide the services of a qualified Commissioning Authority. The responsibilities of the Commissioning Authority are defined in Division 17100 Part 1.5 (E). The Commissioning Authority directs and approves the commissioning work. The commissioning authority for this project is Senegy BCS Inc. (801) 733-7502
- B. Test and Balance Contractor (TAB) Qualifications. The Contractor will provide the services of a qualified test and balance contractor, approved by the Owner, as specified in Section 15991.
- C. Controls Contractor and Lead Technician Qualifications. The Owner as specified in Section 15950 shall approve the Control contractor and the lead technician.

END OF SPECIFICATION SECTION

SECTION 01300 – SUBMITTAL REQUIREMENTS FOR COMMISSIONING

1.1 SUBMITTAL REQUIREMENTS FOR COMMISSIONING

A. Normal Submittals.

1. The Commissioning Authority will receive a copy of the normal submittals and re-submittals for equipment to be commissioned. The Cx authority will also receive a complete listing of all accepted prior approvals for equipment and procedures.
2. The Commissioning Authority will review and approve normal Contractor submittals and re-submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
3. All submittals, re-submittals, and O & M's shall be in electronic format, (*on compact disc or Digital Video Disc (DVD) .pdf*), as well as hard copy.

B. Data for Commissioning.

1. The Contractor will receive a written request from the Commissioning Authority requesting specific information needed about each piece of commissioned equipment or system.
2. 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 actually 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.
3. The Commissioning Authority may request further documentation necessary for the commissioning process.
4. This data request may be made prior to normal submittals.
5. Much of this information is contained in the regular O&M manual submittals normally submitted in the project. Typically, this information is required prior to the regular formal O&M manual submittals.

C. Contractor's responsibility for deviations in submittals from requirements of the Contract Documents is not relieved by the Commissioning Authority's review.

END OF SPECIFICATION SECTION

SECTION 01701 - PROJECT CLOSEOUT - COMMISSIONING

PREREQUISITES TO FUNCTIONAL COMPLETION

- A. All TAB work and the commissioning of Division 17 must be complete prior to Functional Completion, unless approved in writing by the Owner's Project Manager. Functional completion shall constitute project substantial completion. Exceptions to this are the planned control system training performed after occupancy and any required seasonal or approved deferred testing. This includes for all systems, but is not limited to:
 - 1. Completed and signed start-up and pre-functional checklist documentation
 - 2. Requested trend log data
 - 3. Submission of final approved TAB report
 - 4. Completion of all functional testing
 - 5. Required training of Owner personnel completed and approved
 - 6. Submission of the approved O&M manuals
 - 7. All identified deficiencies have been corrected or are approved by the Owner to be excluded from this milestone

- B. The Owner's Project Manager will determine the date of Functional Completion after reviewing the Commissioning Agent's recommendation for Functional Completion.

END OF SPECIFICATION SECTION

SECTION 01730 – OPERATIONS AND MAINTENANCE DATA

- A. The commissioning process requires detailed O&M documentation. Division 1 is alerted to the O&M documentation requirements identified in this section, throughout Section 17100, and other referenced sections.
- B. The commissioning agent's contribution to the O&M manuals is found throughout Section 17100.
- C. The General Contractor shall compile O&M manuals for every piece of equipment and building operating or electrical system with the following format.
 - 1. Quantity: 9
 - 2. Format: 8 ½" x 11" loose-leaf binders. Each binder shall be clearly labeled on the spine. Use as many binders as are required. Do not overload binders. There shall be dividers with permanently marked tabs of card stock separating each section and sub section. Tab labels shall not be handwritten.
 - 3. There shall be a title page and table of contents in the front of each binder for each binder's contents. In each binder, there shall be a main tab for each specification section. Behind the section number tab there shall be the equipment ID tag sub-tab for each piece of major equipment (or group, if small or numerous). These sub-tabs shall be similar to the specification number tabs but of a different color. Behind each equipment name tab shall be the following sections, in the given order, divided by a double weight colored sheet labeled with the title of the section:
 - a. Contractor. The first page behind the equipment tab shall contain the name, address and telephone number of the manufacturer and installing contractor and the 24-hour number for emergency service for all equipment in this section, identified by equipment.
 - b. Submittal and Product Data. This section shall include all approved submittal data, cut sheets, and appropriate shop drawings. If submittal was not required for approval, project specific descriptive product data shall be included.
 - c. Operation and Maintenance Instructions. These shall be the written manufacturer's data with the model and features of this installation clearly marked and edited to omit reference to products or data not applicable to this installation. This section shall include data on the following:
 - 1. Installation, startup, and break-in instructions.
 - 2. All starting, normal shutdown, emergency shutdown, manual operation, seasonal changeover, and normal operating procedures and data, including any special limitations.
 - 3. O&M and installation instructions that were shipped with the unit.
 - 4. Preventative maintenance and service procedures and schedules.
 - 5. Troubleshooting procedures.
 - 6. A parts list edited to omit reference to items which do not apply to this installation.
 - 7. A list of any special tools required to service or maintain the equipment.
 - 8. Performance data, ratings and curves.
 - 9. Warranty which clearly lists conditions to be maintained to keep warranty in effect and conditions that would affect the validity of the warranty.
 - 10. Any service contracts issued and the responsible contract entity including 24 hour emergency contact information.

- d. Supplemental Data. Prepare written text and/or special drawings to provide necessary information where manufacturer's standard printed data is not available and information is necessary for a proper understanding, operation, and maintenance of equipment or systems. Also prepare written text where it is necessary to provide additional information to supplement data included in the manual or project documents.
 - e. Control Drawings. Include the control drawings for the piece of equipment and its components, including the sequence of operation. The controls contractor will provide this section. The drawings will be repeated in the control contractor's O&M submittals. Control submittals shall clearly identify each piece of controlled equipment and shall be in compliance with Controls Specification Section 15950.
 - f. Preventive Maintenance Instructions. This section shall include a list of the location by O&M document name and page number of the any preventative maintenance instructions applicable to this piece of equipment.
4. Controls and Test and Balance (TAB) O&M Manuals. The controls contractor and TAB contractor have special O&M manual preparation requirements in Section 15995 that shall be merged with those of this section.
 5. Architect and Design Engineers' Contributions. The architect and design engineers have special contributions to the O&M manuals as described in Section 17100.
 6. Commissioning Record and Testing Data. There will be a separate manual dedicated to documenting the commissioning process which will include all certifications and testing data and some repeating of O&M data. Description of this manual is found in Section 17100 Part 3.8 (B) and shall be prepared by the commissioning agent.
 7. Electronic Format O&M Data. The Operation and Maintenance data shall also be provided in electronic format, (*on compact disc or Digital Video Disc (DVD) .pdf*), for compilation onto DVD by the general contractor.

END OF SPECIFICATION SECTION

SECTION 15010 – MECHANICAL – GENERAL PROVISIONS

- A. Division 15 will be responsible to carry out the commissioning requirements specified in Section 15995, 15997, and other sections referenced in 17100.

END OF SPECIFICATION SECTION

SECTION 15950 – COMMISSIONING AUTOMATIC CONTROLS

1.1 COMMISSIONING AND QUALITY ASSURANCE

A. Quality Assurance. Quality assurance for automatic controls systems shall be accomplished through the commissioning process consisting of submittal review of system engineering work, documented pre-functional testing and initial checkout, documented functional performance testing, operator training, and O&M documentation. In addition there will be a qualification procedure for the manufacturer and lead installation technician.

B. Related Sections. The general commissioning process procedures and requirements are given in Section 17100 Part 1.3, with responsibilities unique to Division 15 included in Section 15995, including O&M manual documentation and training requirements. The common process requirements for initial system checkout are found in Section 17100 Part 3.6.

1.2 QUALIFICATION OF MANUFACTURER AND LEAD INSTALLING TECHNICIAN

A. Manufacturer and Vendor. Within 21 days after notice to proceed, the controls contractor shall submit to the GC, CM and PM a certified statement, signed by an officer of the manufacturer and vendor which includes the following: name and address of company; name, address and telephone number of the local representative; a general sales bulletin covering the full line of products manufactured; a certification that the products proposed for this contract have been in continuous and successful use for at least 1 year, not including beta testing; and general information covering the functions and characteristics of the systems proposed. In addition, provide a list of four projects which the vendor has installed that are similar in size and complexity to this contract, with the name and telephone number of the contracting officer and facility administrator, size of project, location, and brief description and date of completion.

B. Lead Programmer (LP). The lead programmer will complete the majority of the programming for this project. The LP will personally review and approve all programming by others. Within 14 days after notice to proceed, the controls contractor shall submit the following regarding the LP: name; address; telephone number; certification of training on this system; list of two projects of similar size and complexity to this contract which were primarily programmed by the LP; and for each project the project name, location, description, cost, name and telephone number of the contracting officer and current facility administrator, and date of completion. The Owner must approve a replacement to the LP in writing.

C. Lead Installation Technician (LIT). The automatic controls will be installed under the direct and continuous supervision of a lead technician authorized by the manufacturer. Within 14 days after notice to proceed, the controls contractor shall submit the following regarding the LIT: name; address; telephone number; certification of training on this system; list of two projects of similar size and complexity to this contract which were directly supervised by the LIT; and for each project the project name, location, description, cost, name and telephone number of the contracting officer and current facility administrator, and date of completion. The Owner must approve a replacement to the LIT in writing.

D. Acceptance. A review of the qualifications and action upon the acceptance of the manufacturer and the LIT and LP will be completed by the Owner. If the manufacturer, the proposed product line, or the qualifications of the LIT or LP are not in accordance with the Contract Documents or, in the opinion of the Owner will not result in a satisfactorily completed product, alternatives must be submitted for approval.

2.1 TREND LOGGING CAPABILITIES

A. The control system installed shall be capable of, and set up to; readily trend data with the following minimum features. The controls contractor shall provide time to program at least 20 trending reports at the owner's request. They shall also provide all trending requests of the CxA needed to prove system operation.

1. Any point, physical or calculated, may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each DDC controller's point group.
2. Collection may be by either pre-defined time interval or upon a pre-defined change of value (COV).
3. Each DDC controller panel shall have a dedicated RAM-based buffer for trend data and shall be capable of storing at least 10,000 samples.
4. At least six columns of data can be viewed on the screen at once and can be graphed using a graphing program integral to the control system, with at least four parameters graphed against time on the same graph. The columnar format shall have time down the left column with columns of data to the right (one column for each parameter).
5. The system shall have the ability to graph real-time data of up to four points on the EMS at once, giving each point its own scale.
6. Without any special or difficult conversions, this data shall be able to be designated to be stored as an ASCII delimited file in the same columnar format for use in graphing with normal commercial spreadsheet software.
7. The trend log data is automatically downloaded at appropriate intervals onto the hard drive when space in the field cabinets becomes full, so that no data is lost. This is done without the user having to calculate the size of the trends and download frequency.
8. Any limitations in the trending as to speed of sampling vs. number of sampled points in a given trend, and the effect on actual sampling rate and simultaneousness of the sampling across parameters, shall be clearly explained in writing. Programming and trending setup examples of all representative situations shall be provided.
9. The trends shall be capable of being set up to start sampling all trended points in a given trend or group of trends at the same exact time.
10. Specifications for standard trends shall be able to be set up by the user and be saved by a name and initiated by only recalling the name. *The control contractor shall assist the operators in setting up at least six standard trends during training.*
11. A key for the names and definitions of all point abbreviations (both physical and virtual) shall be provided.
12. The system shall have the ability to automatically accumulate and store run-time hours of digital input and output points and to count events (totalization and counting functions).
13. Ideal, but not required, shall be the capability to graph with the control system software, one or more points against another, rather than just against time.

2.2 TEMPORARY PROGRAMMING AND TESTING TERMINAL

A. If the permanent terminal and display is graphical for viewing values and setpoints, and the update time for the graphical display is considered by the CxA to be too slow, the controls contractor shall provide and set up, during the entire functional testing process, a second input and output terminal with a text based format (in addition to the graphics-capable permanent terminal), which will significantly speed up the point readout update time. Both terminals will be simultaneously active.

2.3 GLOBAL COMMAND CAPABILITY

- A. The system shall be capable of executing from any central control terminal or password controlled access point through the internet, temporary or permanent global commands such as a change in space temperature set point.

2.4 TEST PORTS

- A. The contractor shall provide test ports for handheld instrument readings near all piping system sensors in the primary system (not at the zone level).

2.5 GAGES

- A. The contractor shall provide gages in the following locations, even if included as a sensor and monitored point in the control system:
 1. Pressure gages on both sides of all pumps greater than 1 hp.
 2. Mercury thermometer in the return and supply of all primary thermal plant equipment (well field loop water).

3.1 SUBMITTALS

A. The controls contractor shall submit the manufacturer and lead installation technician data according to Part 1 of this section. Upon acceptance, proceed with shop drawings and other submittal data.

B. The controls contractor shall follow the other submittal requirements in Section 15995, 01300 and 17100.

END OF SPECIFICATION SECTION

SECTION 15991 - TEST, ADJUST AND BALANCE PERFORMANCE QUALIFICATIONS

1.1 COMMISSIONING REQUIREMENTS

A. The TAB will be responsible to carry out the commissioning requirements specified in Section 15991 and throughout Section 17100. Refer to Section 15990.

1.2 QUALIFICATIONS OF TAB CONTRACTOR AND LEAD TECHNICIAN

A. The Contractor will provide the services of a qualified test and balance contractor. The qualifications of the TAB contracting firm shall be submitted, along with the specific qualifications of the lead site technician who will remain on site during all TAB work, within 10 days of notice to proceed. Recent projects shall be listed and described for both the company and the lead technician. Names and telephone numbers of the project contractors and facility managers will be provided.

B. The Owner must approve in writing the qualifications of both the company and the lead technician.

END OF SPECIFICATION SECTION

SECTION 15995 – MECHANICAL SYSTEMS COMMISSIONING

1.1 DESCRIPTION

A. The purpose of this section is to specify the Division 15 contractor's responsibilities in the commissioning process.

B. The systems to be commissioned are listed in Section 17100.1.7.

C. Commissioning requires the participation of Division 15 contractors to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Division 17. **Division 15 shall be familiar with all parts of Division 17** and the commissioning plan issued by the CxA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 RESPONSIBILITIES

A. Mechanical, Controls and TAB Contractors. The commissioning responsibilities applicable to each of the mechanical, controls, and TAB contractors of Division 15 are as follows (all references apply to commissioned equipment only):

Construction and Acceptance Phases

1. Include the cost of commissioning in the contract price.
 2. In each purchase order or subcontract written, include requirements for submittal data, commissioning documentation, O&M data, and training.
 3. Attend a commissioning scoping meeting and other meetings necessary to facilitate the Cx process.
 4. Contractors shall provide the CxA with normal cut sheets and shop drawing submittals of the equipment to be commissioned.
 5. Provide additional requested documentation, prior to normal O&M manual submittals, to the CxA for development of start-up and functional testing procedures.
 - a. 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 actually 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 Agent.
 - b. The Commissioning Agent may request further documentation necessary for the commissioning process.
 - c. This data request may be made prior to normal submittals.
6. Provide a copy of the O&M manuals and submittals of commissioned equipment, through normal channels, to the CxA for review and approval.
7. Contractors 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.

8. Provide limited assistance to the CxA in preparing the specific functional performance test procedures as specified in Section 15997. Subs shall review test procedures to ensure feasibility, safety and equipment protection, and provide necessary written alarm limits to be used during the tests.
9. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the pre-functional checklists from the CxA for all commissioned equipment. Submit to CxA for review and approval prior to startup. Refer to Section 17100 Part 3.4 for further details on start-up plan preparation.
 10. During the startup and initial checkout process, execute the mechanical-related portions of the pre-functional checklists for all commissioned equipment.
 11. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CxA.
 12. 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-related or water-related systems.
 13. 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.
 14. Provide skilled technicians to perform functional performance testing under the direction of the CxA for specified equipment in Section 15997 and 17100 Part 1.7. Assist the CxA in interpreting the monitoring data, as necessary.
 15. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxA, CM, and A/E, and retest the equipment.
 16. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
 17. During construction, maintain as-built red-line drawings for all drawings and final CAD as-builts for contractor-generated coordination drawings, on site for weekly review by engineer and Cx authority. Update after completion of commissioning (excluding deferred testing).
 18. Provide training of the Owner's operating staff using expert qualified personnel, as specified.
 19. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

Warranty Period

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

B. Mechanical Contractor. The responsibilities of the HVAC mechanical contractor during construction and acceptance phases, in addition to those listed in (A) are:

1. Provide startup for all HVAC equipment except for the building automation control system.
2. Assist and cooperate with the TAB contractor and CxA 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. Also provide 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 air-flow stations, measuring devices, and valves.

5. Prepare a preliminary schedule for Division 15 pipe and duct system testing, flushing and cleaning, equipment start-up, and TAB start and completion for use by the CxA. Update the schedule as appropriate.

6. Notify the CM or CxA depending on protocol, when pipe and duct system testing, flushing, cleaning, startup of each piece of equipment, and TAB will occur. Be responsible to notify the CM or CxA, 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 CxA has the scheduling information needed to efficiently execute the commissioning process.

C. Controls Contractor. The commissioning responsibilities of the controls contractor, during construction and acceptance phases in addition to those listed in (A) are:

1. Sequences of Operation Submittals. The Control Contractor's submittal 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:

a. An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components, and function.

b. All interactions and interlocks with other systems.

c. 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.

d. Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included but will generally require additional narrative).

e. Start-up sequences.

f. Warm-up mode sequences.

g. Normal operating mode sequences.

h. Unoccupied mode sequences.

i. Shutdown sequences.

j. Capacity control sequences and equipment staging.

k. Temperature and pressure control: setbacks, setups, resets, etc.

l. Detailed sequences for all control strategies, e.g.: economizer control, optimum start/stop, staging, optimization, demand limiting, etc.

m. Effects of power or equipment failure with all standby component functions.

n. Sequences for all alarms and emergency shut downs.

o. Seasonal operational differences and recommendations.

p. Initial and recommended values for all adjustable settings, setpoints, 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.

q. Schedules, if known.

r. 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 setpoint (Yes / No)
- 6. Monitoring point (Yes / No)
- 7. Intermediate point (Yes / No)
- 8. Calculated point (Yes / No)

Key:

Point Description: DB temp, airflow, etc.

Control or Setpoint: Point that controls equipment and can have its setpoint changed (OSA, SAT, etc.)

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).

Monitoring Point: Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification.

Calculated Point: "Virtual" point generated from calculations of other point values.

The Controls Contractor shall keep the CxA informed of all changes to this list during programming and setup.

- 3. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.
- 4. 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 contractor with any needed unique instruments for setting terminal unit boxes and instruct TAB contractor in their use (handheld control system interface for use around the building during TAB, etc.).
 - b. For a given area, have all required pre-functional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CxA prior to TAB.
 - c. Provide a qualified technician to operate the controls, to assist the TAB contractor in performing TAB, or TOprovide sufficient training for TAB contractor to operate the system without assistance.

5. Assist and cooperate with the CxA 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 in Section 15997 and 16997. Assist in the functional testing of all equipment specified in Section 15997 and 16997. Provide two-way radios during the testing.

b. Execute all control system trend logs specified in Section 15997 and 16997.

6. 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, according to the process in Section 17100 Part 3.4. At a 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 CxA and TAB contractor for this determination.

7. Provide a signed and dated certification to the CxA and CM 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.

8. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control, and virtual points as specified in Section 15950.

9. 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).

D. TAB Contractor. The duties of the TAB contractor, in addition to those listed in (A) are:

1. Six weeks prior to starting TAB, submit to the CM the qualifications of the site technician for the project including the name of the contractors and facility managers of recent projects on which the technician was lead. The Owner will approve the site technician's qualifications for this project. In the event the owner does not approve the site technician's qualifications, the contractor shall provide a minimum of two alternate individuals for review and approval within three business days.

2. Submit the outline of the TAB plan and approach for each system and component to the CxA, CM, and the controls contractor six weeks prior to starting the TAB. This plan will be developed after the TAB contractor 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 water side.

g. List of all air flow, water flow, sound level, system capacity, and efficiency measurements to be performed and a description of specific test procedures, parameters, and 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 CxA and CM at least twice a week.

5. Communicate in writing to the controls contractor all setpoint 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 CxA and the 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 CxA with any requested data, gathered, but not shown on the draft reports.

8. Provide a final TAB report for the CxA with details, as in the draft.

9. Conduct functional performance tests and checks on the original TAB as specified for TAB in Section 15997.

E. Mechanical Designer. Refer to Section 17100 Part 1.5 (D) for the responsibilities of the mechanical designer.

1.3 RELATED WORK

A. Refer to Section 17100 Part 1.4 for a listing of all sections where commissioning requirements are found.

B. Refer to Section 17100 Part 1.7 for systems to be commissioned; and section 17100 Part 3.6 and 15997 for functional testing requirements.

2.1 TEST EQUIPMENT

A. Division 15 contractors shall provide all test equipment necessary to fulfill the testing requirements of this Division.

B. Refer to Section 17100 Part 2.1 for additional Division 15 requirements.

3.1 SUBMITTALS

A. Division 15 contractors shall provide submittal documentation relative to commissioning as required in this Section Part 1, Section 01300 and Section 17100 Part 3.3.

3.2 STARTUP

A. The HVAC, mechanical, and controls contractors shall follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in 17100 Part 1.5. Division 15

contractors have start-up responsibility and are required to complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the commissioning agent or Owner.

B. Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CxA and CM. Beginning system testing before full completion does not relieve the Contractor from fully completing the system, including all pre-functional checklists as soon as possible.

3.3 TAB

Refer to the TAB responsibilities in Part 1.2 above.

3.4 FUNCTIONAL PERFORMANCE TESTS

Refer to Section 17100 Part 1.7 for a list of systems to be commissioned, to Part 3.6 for a description of the process, and to Section 15997 for specific details on the required functional performance tests.

3.5 TESTING DOCUMENTATION, NON-CONFORMANCE AND APPROVALS

A. Refer to Section 17100 Part 3.4 (F) for specific details on non-conformance issues relating to pre-functional checklists and tests.

B. Refer to Section 17100 Part 3.7 for issues relating to functional performance tests.

3.6 OPERATION AND MAINTENANCE (O&M) MANUALS, CONTROL CONTRACTOR REQUIREMENTS, TAB

A. The following O&M manual requirements do not replace O&M manual documentation requirements elsewhere in these specifications.

B. Division 15 contractors shall compile and prepare documentation for all equipment and systems covered in Division 15 and deliver this documentation to the GC for inclusion in the O&M manuals, according to this section and Section 01730, prior to the training of owner personnel. An electronic copy, (*on compact disc or Digital Video Disc (DVD) .pdf*), of all O&M information shall be included as well as the hard copy.

C. The CxA shall receive a copy of the O&M manuals for review.

D. Special Control System O&M Manual Requirements. In addition to documentation that may be specified elsewhere, the controls contractor shall compile and organize, at minimum, the following data on the control system in labeled 3-ring binders with indexed tabs:

1. Three copies of the controls training manuals in a separate manual from the O&M manuals.
2. Operation and Maintenance Manuals containing:
 - a. Specific instructions on how to perform and apply all functions, features, modes, etc. mentioned in the controls training sections of this specification and other features of this system. These instructions shall be step-by-step. Indexes and clear tables of contents shall be included. The detailed technical manual for programming and customizing control loops and algorithms shall be included.
 - b. Full as-built set of control drawings (refer to Section 3.1 above for details).
 - c. Full as-built sequence of operations for each piece of equipment.
- d. Full points list. In addition to the updated points list required in the original submittals (Part 1 of this section), a listing of all rooms shall be provided with the following information for each room:
 1. Floor
 2. Room number
 3. Room name
 4. Air handler unit ID

5. Reference drawing number
 6. Minimum cfm
 7. Maximum cfm
- e. Full print out of all schedules and set points after testing and acceptance of the system.
 - f. Full as-built print out of software program.
 - g. Electronic copy on disk of the entire program for this facility.
 - h. Marking of all system sensors and thermostats on the as-built floor plan and mechanical drawings with their control system designations.
 - i. Maintenance instructions, including sensor calibration requirements, and methods by sensor type, etc.
 - j. Control equipment component submittals, parts lists, etc.
 - k. Warranty requirements.
 - l. Copies of all checkout tests and calibrations performed by the Contractor (not commissioning tests).

3. The manual shall be organized and subdivided with permanently labeled tabs for each of the following data in the given order:

- a. Sequences of operation
- b. Control drawings
- c. Points lists
- d. Controller / module data
- e. Thermostats and timers
- f. Sensors and DP switches
- g. Valves and valve actuators
- h. Dampers and damper actuators
- i. Program setups (software program printouts)

4. Field checkout sheets and trend logs should be provided to the CxA for inclusion in the Commissioning Record Book.

E. Special TAB Documentation Requirements. The TAB contractor will compile and submit the following, with other documentation that may be specified elsewhere in the *Specifications*:

1. Final report containing an explanation of the methodology, assumptions, test conditions, and the results in a clear format with designations of all uncommon abbreviations and column headings.

2. The TAB contractor shall mark on the drawings where all traverse and other critical measurements were taken and cross reference the location in the TAB report.

F. Review and Approvals. Review of the commissioning related sections of the O&M manuals shall be made by the A/E and by the CxA. Refer to Section 17100 Part 3.8 for details.

3.7. TRAINING OF OWNER PERSONNEL

A. General Contractor. The General Contractor shall be responsible for training coordination and scheduling, and ultimately for ensuring that training is completed. Refer to Section 17100 Part 3.9 for additional details.

B. Commissioning Authority. The Commissioning Authority shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 17100 Part 3.9 for additional details.

C. Mechanical Contractor. The mechanical contractor shall have the following training responsibilities:

1. Provide the CxA with a training plan, two weeks before the planned training, according to the outline described in Section 17100 Part 3.9.
2. Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to: pumps, heat exchange, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, controls and water treatment systems, etc.
3. Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation including: startup, shutdown, fire/smoke alarm, power failure, etc.
4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
5. The appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment is required. More than one party may be required to execute the training.
6. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
7. The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
8. Training shall include:
 - a. Use of the printed installation, operation, and maintenance instruction material included in the O&M manuals.
 - b. A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed, and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover, and any emergency procedures.
 - c. Discussion of relevant health and safety issues and concerns.
 - d. Discussion of warranties and guarantees.
 - e. Common troubleshooting problems and solutions.
 - f. Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.
 - g. Discussion of any peculiarities of equipment installation or operation.
 - h. The format and training agenda in *The HVAC Commissioning Process, ASHRAE Guideline 0-2005*, is recommended.
 - i. Classroom sessions shall include the use of overhead projections, slides, and/or video/audio-taped material as might be appropriate.
9. Hands-on training shall include start-up, operation in all modes possible including manual, shut-down, and any emergency procedures and preventative maintenance for all pieces of equipment.
10. The mechanical contractor shall fully explain and demonstrate the operation, function, and overrides of any local packaged controls not *controlled* by the central control system.
11. Training shall occur after functional testing is complete, unless approved otherwise by the Project Manager.

12. Duration of Training. The mechanical contractor shall provide training on each piece of equipment according to the following schedule.

Note: Mechanical engineer should fill in hours

<u>Hours</u>	<u>System</u>
4	Air Handling Units
1	Mechanical Seismic Control
4	Piping Systems
1	Chemical Treatment
1	Variable Speed Drives
1	Return Fan/Relief Fan
1	Computer Room Units
1	Specialty Exhaust Fans
1	Service Hot Water Heaters
4	Fire Protection System
1	Fire Sprinklers
1	Irrigation
8	Building Automation System
8	Testing Adjusting and Balancing

D. Controls Contractor. The controls contractor shall have the following training responsibilities:

1. Provide the CxA with a training plan four weeks before the planned training according to the outline described in Section 17100 Part 3.9.
2. The controls contractor shall provide designated Owner personnel training on the control system in this facility. The intent is to clearly and completely instruct the Owner on all the capabilities of the control system.
3. Training manuals. The standard operating manual for the system and any special training manuals will be provided for each trainee, with three extra copies left for the O&M manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the O&M manuals. Manuals shall include detailed description of the subject matter for each session. The manuals will cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals *and* in all software displays. Manuals will be approved by the CxA. Copies of audiovisuals shall be delivered to the Owner.
4. The trainings will be tailored to the needs and skill-level of the trainees.
5. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. The Owner shall approve the instructor prior to scheduling the training.
6. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
7. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
8. There shall be three training sessions:
 - a. Training I. Control System. The first training shall consist of **8 hours** of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion each student, using appropriate documentation,

should be able to perform elementary operations and describe general hardware architecture and functionality of the system.

b. Training II. Building Systems. The second session shall be held on-site for a period of **8 hours** of actual hands-on training after the completion of system commissioning. The session shall include instruction on:

1. Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system including: HVAC systems, lighting controls, and any interface with security and communication systems.
2. Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing setpoints and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
3. All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically, and printing trends. Trainees will actually set-up trends in the presence of the trainer.
4. Every screen shall be completely discussed, allowing time for questions.
5. Use of keypad or plug-in laptop computer at the zone level.
6. Use of remote access to the system via phone lines or networks.
7. Setting up and changing an air terminal unit controller.
8. Graphics generation.
9. Point database entry and modifications.
10. Understanding DDC field panel operating programming (when applicable).

c. Training III. The third training will be conducted on-site six months after occupancy and consist of **8 hours** of training. The session will be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.

E. TAB. The TAB contractor shall have the following training responsibilities:

1. TAB shall meet for **4 hours** with facility staff after completion of TAB and instruct them on the following:

- a. Go over the final TAB report, explaining the layout and meanings of each data type.
- b. Discuss any outstanding deficient items in control, ducting or design that may affect the proper delivery of air or water.
- c. Identify and discuss any terminal units, duct runs, diffusers, coils, fans and pumps that are close to or are not meeting their design capacity.
- d. Discuss any temporary settings and steps to finalize them for any areas that are not finished.
- e. Other salient information that may be useful for facility operations relative to TAB.

3.8. DEFERRED TESTING

- A. Refer to Section 17100 Part 3.10 for requirements of deferred testing.

END OF SPECIFICATION SECTION

SECTION 15997 – MECHANICAL TESTING REQUIRMENTS

1.1 INCLUDED SYSTEMS AND EQUIPMENT

A. The following is a list of the equipment and system test requirements included in this section:

- Building Automation System
- HVAC Piping & Specialties
- HVAC Pumps
- HVAC Water Treatment
- Heating Systems
- Cooling Systems
- Air Handling Units
- Air Distribution Systems (Terminal Units)
- Duct Work and Accessories (Fire Smoke Dampers)
- Electronic Controls
- Test and Balance (TAB) Work

1.2 DESCRIPTION

This section specifies the functional testing requirements for Division 15 systems and equipment. From these requirements the Commissioning Authority (CxA) shall develop step-by-step procedures to be executed by the Subcontractors. The general functional testing process, requirements, and test method definitions are described in Section 17100 Part 3.6. The test requirements for each piece of equipment or system contain the following:

CxA The contractors responsible for executing the tests, under the direction of the

- A list of the integral components being tested
- Pre-functional checklists associated with the components
- Functions and modes to be tested
- Required conditions of the test for each mode
- Special procedures
- Required methods of testing
- Required monitoring
- Acceptance criteria
- Sampling strategies allowed

1.3 PREREQUISITES

The following applicable generic prerequisite checklist items are required to be completed and checked off by CxA prior to functional testing.

- ___ All related equipment has been started up and start-up reports and pre-functional checklists submitted and approved ready for functional testing.
- ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning, and sensor calibrations completed.
- ___ Piping system flushing complete and required report approved.
- ___ Water treatment system complete and operational.
- ___ Vibration control report approved (if required).
- ___ Test and balance (TAB) complete and approved for the hydronic system.
- ___ All A/E punchlist items for this equipment corrected.
- ___ These functional test procedures reviewed and approved by installing contractor.
- ___ Safeties and operating ranges reviewed by the CxA.
- ___ Test requirements and sequences of operation attached.
- ___ Schedules and setpoints attached.
- ___ False loading equipment, system, and procedures ready.
- ___ Crankcase heaters have been on long enough for immediate startup.
- ___ Sufficient clearance around equipment for servicing.
- ___ Record of all values for pre-test setpoints changed to accommodate testing has been made and a check box provided to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).
- ___ Other miscellaneous checks of the pre-functional checklist and start-up reports completed successfully.

1.4 MONITORING

- A. Monitoring is a method of testing as a stand-alone method or to augment manual testing.
- B. All points listed in the required monitoring section of the test requirements which are control system monitored points shall be trended by the controls contractor. At the option of the CxA, some control system monitoring may be replaced with datalogger monitoring. At the CxA's request, the controls contractor shall trend up to 20% more points than listed herein at no extra charge.
- C. Hard copies of monitored data must be in columnar format with time down the left column and at least 5 columns of point values on the same page.
- D. Graphical output is desirable, and will be required for all output, if the system can produce it.

PART 2 - PRODUCTS

-- NOT APPLICABLE --

PART 3 - EXECUTION

3.1 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. CxA: to witness, direct, and document testing.

B. Integral Components or Related Equipment Being Tested.

1. TAB water-side
2. TAB air-side

C. Prerequisites. The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent 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. 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 Division.

<u>Test or Check</u>	<u>Test Method</u>	<u>Required Seasonal Test³</u>
<p>1. A random sample of up to 20% of 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 failure¹ of more than 10% of the selected items of a given system² 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 20% of the air handlers. Other selected data to be verified will be made known upon day of testing.</p>	Demonstration	
<p>2. Verify that final settings of all valves, splitters, dampers and other adjustment devices have been permanently marked by the TAB Contractor.</p>	Demonstration	
<p>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 setpoints 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.</p>	Demonstration	
<p>4. Verification that the water system is being controlled to the lowest possible pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control setpoints 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.</p>	Demonstration	

¹Failure of an item is defined as follows:

For air flow of supply and return: a deviation of more than 10% of instrument reading.

For minimum outside air flow: 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 .5°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).

²Examples of a "system" are: the air distribution system served by one air handler or the hydronic chilled water supply system served by a chiller or the condenser water system. Systems can be defined smaller if inaccuracies in TAB work within the smaller defined system will have little or no impact on connected systems.

³Cooling 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
- I. Acceptance Criteria. (referenced by function or mode ID)
Provided in footnote to test table above.
- J. Sampling Strategy for Identical Units.
Described in test table above.

END OF REQUIREMENTS FOR TAB TEST

4.1 EQUIPMENT FUNCTIONAL TESTING

Sample functional tests will be distributed and discussed at the mandatory pre-bid meeting, and also discussed during construction.

END OF SPECIFICATION SECTION

SECTION 16010 – ELECTRICAL – GENERAL PROVISIONS

- A. Division 16 will be responsible to carry out the commissioning requirements specified in Section 16995, 16997, and other sections referenced in 17100.

END OF SPECIFICATION SECTION

SECTION 16995 - ELECTRICAL SYSTEMS COMMISSIONING

1.1 DESCRIPTION

- A. The purpose of this section is to specify Division 16 responsibilities in the commissioning process which are being directed by the CxA. Other electrical systems testing are required under the direction of the CM.
- B. The list of commissioned equipment and systems is found in Section 17100 Part 1.7.
- C. Commissioning requires the participation of Division 16 contractors to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Division 17. **Division 16 shall be familiar with all parts of Division 17** and the commissioning plan issued by the CxA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 RESPONSIBILITIES

- A. Electrical Contractors. The commissioning responsibilities applicable to the electrical contractor are as follows (*all references apply to commissioned equipment only*):

Construction and Acceptance Phases

1. Include the cost of commissioning in the contract price.
 2. In each purchase order or subcontract written, include requirements for submittal data, O&M data, and training.
 3. Attend a commissioning scoping meeting and other necessary meetings scheduled by the CxA to facilitate the Cx process.
 4. Contractors shall provide normal cut sheets and shop drawing submittals to the CxA of commissioned equipment.
 5. Provide additional requested documentation, prior to normal O&M manual submittals, to the CxA for development of start-up and functional testing procedures.
 - a. Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, 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 actually 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 Agent.
 - b. The Commissioning Agent may request further documentation necessary for the commissioning process.
 - c. This data request may be made prior to normal submittals.
6. Provide a copy of the O&M manuals submittals of commissioned equipment, through normal channels, to the CxA for review and approval.
7. Contractors 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.
8. Provide assistance to the CxA in preparation of the specific functional performance test procedures specified in Section 16997. Subs shall review test procedures to ensure feasibility, safety and equipment protection, and provide necessary written alarm limits to be used during the tests.

9. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and pre-functional checklists from the CxA. Submit manufacturer's detailed start-up procedures and full start-up plan and procedures and other requested equipment documentation to CxA for review.
10. During the startup and initial checkout process, execute and document the electrical-related portions of the pre-functional checklists provided by the CxA for all commissioned equipment.
11. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CxA.
12. Address current A/E punch list items before functional testing. Torque wrench, mark bolts, main lugs, wire tags, boxes tagged, and on redline as built – visual verification only.
13. Provide skilled technicians to execute starting of equipment and to execute 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.
14. Perform functional performance testing under the direction of the CxA for specified equipment in Section 16997 and 17100 Part 1.7. Assist the CxA in interpreting the monitoring data as necessary.
15. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxA, CM, and A/E, then retest the equipment.
16. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
17. During construction, maintain as-built red-line drawings for all drawings and final CAD as-builts for contractor generated coordination drawings. Update after completion of commissioning (excluding deferred testing). Prepare red line as-built drawings for all drawings and final as-builts for contractor-generated coordination drawings.
18. Provide training of the Owner's operating personnel as specified.
19. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

Warranty Period

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

B. Electrical Designer/Engineer

Refer to Section 17100 Part 1.5 (D) for the responsibilities of the Electrical Designer/Engineer.

1.3 RELATED WORK

- A. Refer to Section 17100 Part 1.4 for a listing of all sections where commissioning requirements are found.
- B. Refer to Section 17100 Part 1.7 for systems to be commissioned and section 17100 Part 3.6 and 16997 for functional testing requirements.

2.1 TEST EQUIPMENT

- A. Division 16 contractors shall provide all test equipment necessary to fulfill the testing requirements of this Division.

B. Refer to Section 17100 Part 2.1 for additional Division 16 requirements.

3.1 SUBMITTALS

A. Division 16 contractors shall provide submittal documentation relative to commissioning to the CxA as requested by the CxA. Refer to Section 17100 Part 3.3 for additional Division 16 requirements.

3.2 STARTUP

A. The electrical contractors shall follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in 17100 Part 3.4. Division 16 contractors have start-up responsibility and are required to complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the commissioning agent or Owner.

B. Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CxA and CM. Beginning system testing before full completion does not relieve the Contractor from fully completing the system, including all pre-functional checklists as soon as possible.

3.3 FUNCTIONAL PERFORMANCE TESTS

A. Refer to Section 17100 Part 1.7 for a list of systems to be commissioned, to Part 3.6 for a description of the process, and to Section 16997 for specific details on the required functional performance tests.

3.4 TESTING DOCUMENTATION, NON-CONFORMANCE AND APPROVALS

A. Refer to Section 17100 Part 3.4 for specific details on non-conformance issues relating to pre-functional checklists and tests.

B. Refer to Section 17100 Part 3.7 for issues relating to functional performance tests.

3.5 OPERATIONS AND MAINTENANCE (O&M) MANUALS

A. Division 16 contractors shall compile and prepare documentation for all equipment and systems covered in Division 16 and deliver to the GC for inclusion in the O&M manuals, according to Section 01730.

B. The CxA shall receive a copy of the O&M manuals for review.

3.6. TRAINING OF OWNER PERSONNEL

A. General Contractor. The GC shall be responsible for training coordination, scheduling, and ultimately ensuring that training is completed. Refer to Section 17100 Part 3.9 for additional details.

B. Commissioning Authority. The CxA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 17100 Part 3.9 for additional details.

C. Electrical Contractor. The electrical contractor shall have the following training responsibilities:

1. Provide the CxA with a training plan two weeks before the planned training according to the outline described in Section 17100 Part 3.9.

2. Provide designated Owner personnel with comprehensive training in the understanding of the systems and the operation and maintenance of each major piece of commissioned electrical equipment or system.

3. Training shall start with classroom sessions, if necessary, followed by hands on training on each piece of equipment which shall illustrate the various modes of operation including: startup, shutdown, fire/smoke alarm, power failure, etc.

4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.

5. The appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor, or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment is required. More than one party may be required to execute the training.

6. The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.

7. Training shall include:

a. Use the printed installation, operation and maintenance instruction material included in the O&M manuals.

b. Include a review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance; special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut down, seasonal changeover and any emergency procedures.

c. Discuss relevant health and safety issues and concerns.

d. Discuss warranties and guarantees.

e. Cover common troubleshooting problems and solutions.

f. Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.

g. Discuss any peculiarities of equipment installation or operation.

h. The format and training agenda in *Guidelines for Commissioning HVAC Systems, ASHRAE Guideline 0-2005* is recommended.

i. Classroom sessions shall include the use of overhead projections, slides, video and audio taped material as might be appropriate.

8. Hands-on training shall include start-up, operation in all modes possible, including manual, shut down and any emergency procedures and maintenance of all pieces of equipment.

9. The electrical contractor shall fully explain and demonstrate the operation, function, and overrides of any local packaged controls not *controlled* by the central control system.

10. Training shall occur after functional testing is complete unless approved otherwise by the Project Manager.

11. Duration of Training. The electrical contractor shall provide training on each piece of equipment according to the following schedule.

Note: Engineer should enter training hours required

	Fire Alarm System
	Lighting Controls
	Emergency Generator
	UPS
	Security System
	Telecom and Data

3.7. DEFERRED TESTING

- A. Refer to Section 17100 Part 3.10 for requirements of deferred testing.

END OF SPECIFICATION SECTION

SECTION 16997 – ELECTRICAL TESTING REQUIREMENTS

1.1. INCLUDED SYSTEMS AND EQUIPMENT

The following is a list of the equipment and system test requirements included in this section:

Lighting sweep controls
Emergency power and UPS system

1.2 DESCRIPTION

A. This section specifies the functional testing requirements for Division 16 systems and equipment. From these requirements, the Commissioning Authority (CxA) shall develop step-by-step procedures to be executed by the Subs. The general functional testing process, requirements, and testing method definitions are described in Section 17100 Part 3.6. The test requirements for each piece of equipment or system contain the following:

CxA	The contractors responsible for executing the tests, under the direction of the
	A list of the integral components being tested
	Pre-functional checklists associated with the components
	Functions and modes to be tested
	Required conditions of the test for each mode
	Special procedures
	Required methods of testing
	Required monitoring
	Acceptance criteria
	Sampling strategies allowed

1.3 PREREQUISITES

The following applicable generic prerequisite checklist items are required to be completed and checked off by CxA prior to functional testing.

- ___ All related equipment has been started up and start-up reports and pre-functional checklists submitted and approved ready for functional testing.
- ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.
- ___ All A/E punchlist items for this equipment corrected.
- ___ These functional test procedures reviewed and approved by installing contractor.
- ___ Safeties and operating ranges reviewed by the CxA.
- ___ Test requirements and sequences of operation attached.
- ___ Schedules and setpoints attached.
- ___ Sufficient clearance around equipment for servicing and code compliance.
- ___ Record of all values for pre-test setpoints changed to accommodate testing has been made and a check box provided to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).
- ___ Other miscellaneous checks of the pre-functional checklist and start-up reports completed successfully.

1.4 MONITORING

- A. Monitoring is a method of testing as a stand-alone method or to augment manual testing.
- B. All points listed in the required monitoring section of the test requirements which are control system monitored points shall be trended by the controls contractor. At the option of the CxA, some control system monitoring may be replaced with datalogger monitoring. At the CxA's request, the controls contractor shall trend up to 20% more points than listed at no extra charge.
- C. Hard copies of monitored data must be in columnar format with time down the left column and at least 4 columns of point values on the same page.
- D. Graphical output is a desirable option, if the system can produce it.

2.1 LIGHTING SWEEP CONTROLS

- A. Parties Responsible to Execute Functional Test.
 - 1. Controls contractor: operate the controls.
 - 2. Electrical contractor: assist in testing sequences.
 - 3. CxA: to witness, direct, and document testing.
- B. Integral Components or Related Equipment Being Tested. Lighting Sweep Controls
- C. Prerequisites. The applicable prerequisite checklist items listed in the beginning of Section 16997 shall be listed on each functional test form and checked off prior to functional testing.
- D. Sample Tests will be distributed at the mandatory pre-bid meeting.

END OF REQUIREMENTS FOR SWEEP CONTROL TEST

2.2 DAYLIGHT DIMMING CONTROLS

- A. Parties Responsible to Execute Functional Test.
 - 1. Controls contractor: operate the controls.
 - 2. Electrical contractor: assist in testing sequences.
 - 3. CxA: to witness, direct, and document testing.
- B. Integral Components or Related Equipment Being Tested. Daylight Dimming Controls
- C. Prerequisites. The applicable prerequisite checklist items listed in the beginning of Section 16997 shall be listed on each functional test form and checked off prior to functional testing.
- D. Sample Tests will be distributed at the mandatory pre-bid meeting.

END OF REQUIREMENTS FOR DAYLIGHT DIMMING TEST

2.3 EMERGENCY POWER AND UNINTERRUPTIBLE POWER SUPPLY SYSTEM

A. Parties Responsible to Execute or Participate in Functional Test.

1. Controls contractor: operate the controls.
2. Electrical contractor: provide all testing instruments and assist in testing sequences and debugging.
3. Mechanical contractor: assist in testing sequences and debugging.
4. Electrical design engineer: assist in testing sequences.
5. Security system contractor, local and remote monitoring site: report communication response.
6. Owner staff at regional monitoring site: report communication response.
7. Project Owner and facility representatives: assist in testing sequences and debugging
8. Commissioning authority: coordinate and document testing.

B. Integral Components or Related Equipment Being Tested.

1. Generator
2. Automatic transfer switch
3. Uninterruptible power supply
4. Building control, HVAC, lighting, fire alarm, telecommunications, elevator, and security systems

C. Prerequisites. The applicable prerequisite checklist items listed in the beginning of Section 16997 shall be listed on each functional test form and checked off prior to functional testing.

D. Sample Tests will be distributed at the mandatory pre-bid meeting.

END OF REQUIREMENTS FOR DAYLIGHT DIMMING TEST

Section 17100 – PROJECT COMMISSIONING REQUIREMENTS AND PROCEDURES

1.1 DESCRIPTION

- A. Commissioning. Commissioning is a systematic process of ensuring that all building systems perform interactively according to the design intent and the owner's operational needs. This is achieved by beginning in the design phase, documenting design intent, and continuing through construction, acceptance and the warranty period with actual verification of performance. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment startup, control system calibration, testing and balancing, performance testing, and training.

Commissioning during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:

1. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to 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 left on site is complete.
4. Verify that the Owner's operating personnel are adequately trained.

B. 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.

C. Abbreviations. The following are common abbreviations used in the *Specifications* and in the *Commissioning Plan*. Definitions are found in Section 1.6.

A/E	Architect and Design Engineers	FT	Functional Performance Test
CxA	Commissioning Authority	GC	General Contractor (prime)
CC	Controls Contractor	MC	Mechanical Contractor
CM	Construction Manager (the Owner's Representative)	PC	Pre-functional Checklist
Cx	Commissioning	PM	Project Manager (of the Owner)
Cx Plan	Commissioning Plan Document	Subs	Subcontractors to General
EC	Electrical Contractor	TAB	Test Adjust and Balance Contractor

1.2 COORDINATION

A. Commissioning Team. The members of the commissioning team consist of the Commissioning Authority (CxA), the Project Manager (PM), the Designated Representative of the Owner's Construction Management Firm (CM), the General Contractor (GC or Contractor), the Architect and Design Engineers, the Mechanical Contractor (MC), the Electrical Contractor (EC), the TAB Representative, the Controls Contractor (CC), any other installing subcontractors or suppliers of equipment. If known, the Owner's building or plant Operator/Engineer is also a member of the commissioning team.

B. Management. The Owner hires the CxA directly. The CxA directs and coordinates the commissioning activities and then reports to the owner's Project Manager who is part of the CM team. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents. The CxA's responsibilities are the same regardless of who hired the CxA. Refer to Section 17100 Part 1.6 for additional management details. The organization chart found in 17100 Part 1.5 clarifies the roles.

C. Scheduling. The CxA will work with the CM and GC according to established protocols to schedule the commissioning activities. The CxA will provide sufficient notice to the CM and GC for scheduling commissioning activities. The GC will integrate all commissioning activities into the master schedule. All parties will address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process.

The CxA will provide the initial schedule of primary commissioning events at the commissioning scoping meeting. The *Commissioning Plan—Construction Phase* provides a format for this schedule. As construction progresses the CxA develops more detailed schedules. The Commissioning Plan also provides a format for detailed schedules.

1.3 COMMISSIONING PROCESS

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

1. Commissioning during construction begins with a scoping meeting conducted by the CxA where the commissioning process is reviewed with the commissioning team members.
2. Additional meetings will be required throughout construction, scheduled by the CxA with necessary parties attending to plan, scope, coordinate, schedule future activities, and resolve problems.
3. Equipment documentation is submitted to the CxA during normal submittals, including detailed start-up procedures.
4. The CxA works with the Subs in developing startup plans and startup documentation formats, including providing the Subs with pre-functional checklists to be completed during the startup process.
5. In general, the checkout and performance verification proceeds from simple to complex, from component level to equipment to systems and intersystem levels with pre-functional checklists being completed before functional testing.
6. The Subs, under their own direction, execute and document the pre-functional checklists and perform startup and initial checkout. The CxA documents that the checklists and startup were completed according to the approved plans. This may include the CxA witnessing start-up of selected equipment.
7. The CxA develops specific equipment and system functional performance test procedures. The Subs review the procedures.
8. The procedures are executed by the Subs under the direction of, and documented by the CxA.
9. Items of non-compliance in material, installation, or setup are corrected at the Sub's expense and the system retested.
10. The CxA reviews the O&M documentation for completeness.
11. Commissioning is completed before Substantial Completion.
12. The CxA reviews, pre-approves, and coordinates the training provided by the Subs and verifies that training is completed.
13. Deferred testing is conducted as specified or required.

1.4 RELATED WORK

A. Specific commissioning requirements are given in the following sections of these specifications. All of the following sections apply to the Work of this section.

00800	Supplementary Conditions	Provides for
01140	Coordination	Introduces commissioning, refers to Division 17, and requires that the GC hire a qualified CxA.
01300	Submittals	Alerts all parties that additional detail in submittals may be required and directs to Division 17.
01700	Project Close-out	Defines Substantial Completion and Functional Completion milestones relative to commissioning.
01730	O&M Data	Alerts all parties that O&M documentation may be more detailed and directs to Division 17.
15010	Mechanical General	Alerts the mechanical contractor to Cx responsibilities in 15995.
15950	Automatic Controls	Lists special requirements and alerts the controls contractor of the special requirements of the control contractor and control system in 15995.
15991	TAB	Alerts the TAB of Cx responsibilities in 15995.
15995	Mechanical Cx	Describes the Cx responsibilities of the mechanical, controls, and TAB contractors and the pre-functional testing and startup responsibilities of each. Points to 15997 for functional testing requirements.
15998	Sample Forms	
15997 requirements Requirements	Mechanical Testing	Describes the specific functional testing for Division 15 equipment in the project.
16010 responsibilities in 16995.	Electrical General	Alerts the electrical contractor of Cx
16995	Electrical Cx	Describes the Cx responsibilities of the electrical contractor.
16997	Electrical Testing	Describes the specific functional testing requirements. Requirements for Division 16 equipment in the project.
17100	Commissioning	Describes the commissioning process, responsibilities common to all parties, responsibilities of the A/E, CxA, PM, GC, and Suppliers, focusing on the CxA. The Unique MC, CC, TAB, AND EC responsibilities are included in Div. 15 and 16.

1.5 RESPONSIBILITIES

A. The responsibilities of various parties in the commissioning process are provided in this section. The responsibilities of the mechanical contractor, TAB and controls contractor are in Division 15. The responsibilities of the electrical contractor are in Division 16. It is noted that the services for the Project Manager, Construction Manager, Architect, HVAC mechanical and electrical designers/engineers, and Commissioning authority are not provided for in this contract. That is, the Contractor is not responsible for providing their services. Their responsibilities are listed here to clarify the commissioning process.

B. All Parties

Attend commissioning scoping meeting and additional meetings as necessary.

C. Architect (of A/E)

Construction and Acceptance Phase

1. The Owner manages the CxA contract.
2. Attend the commissioning scoping meeting and selected commissioning team meetings.
3. Perform normal submittal review, construction observation, as-built drawing preparation, O&M manual preparation, etc., as contracted.
4. Provide any design narrative documentation requested by the CxA.
5. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
6. Prepare and submit final as-built design intent documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.

Warranty Period

Coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning.

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

Construction and Acceptance Phase

1. Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted. One site observation should be completed just prior to system startup.
2. Provide any design narrative and sequences documentation requested by the CxA. The designers shall assist (along with the contractors) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings, or equipment documentation is not sufficient for writing detailed testing procedures.
3. Attend commissioning scoping meetings and other selected commissioning team meetings.
4. Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
5. Prepare and submit the final as-built design intent and operating parameters documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.
6. From the Contractor's red-line drawings, edit and update one-line diagrams developed as part of the design narrative documentation and those provided by the vendor as shop drawings for the chilled and hot water, condenser water, domestic water, steam and condensate systems; supply, return and exhaust air systems, and emergency power system.
7. Approve the pre-functional checklists for major pieces of equipment for sufficiency prior to their use.

8. Approve the functional test procedure forms for major pieces of equipment, for sufficiency prior to their use.
9. Witness testing of selected pieces of equipment and systems: Heat pump systems including controls, ground source water loop performance, audio/video systems, fire alarm system, and lighting control system.

Warranty Period

Participate in the resolution of non-compliance, non-conformance and design deficiencies identified during commissioning during warranty-period commissioning.

E. Commissioning Authority (CxA)

The CxA is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management. The CxA may assist with problem solving non-conformance or deficiencies, but ultimately that responsibility resides with the general contractor and the A/E. The primary role of the CxA is to develop and coordinate the execution of a testing plan, observe and document performance—that systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, checkout and functionally test equipment and systems, except for specified testing with portable data-loggers which shall be supplied and installed by the CxA.

Construction and Acceptance Phase

commissioning
meetings.

1. Coordinates and directs the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules, and technical expertise.
2. Coordinate the commissioning work and, with the GC and CM, ensure that activities are being scheduled into the master schedule.
3. Revise, as necessary, the *Commissioning Plan—Construction Phase*.
4. Plan and conduct a commissioning scoping meeting and other commissioning
5. Request and review additional information required to perform commissioning tasks including: O&M materials and contractor start-up and checkout procedures.
6. Before startup, gather and review the current control sequences and interlocks and work with contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
7. Review and approve normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
8. Write and distribute pre-functional tests and checklists.
9. Develop an enhanced start-up and initial systems checkout plan with Subs.
 10. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction-meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.
 11. Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify owner's project manager of any deficiencies in results or procedures.
 12. Witness all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Document this testing and include the documentation in O&M manuals. Notify owner's project manager of any deficiencies in results or procedures.

13. Approve pre-functional tests and checklist completion by reviewing pre-functional checklist reports and by selected site observation and spot-checking.
14. Approve systems startup by reviewing start-up reports and by selected site observation.
15. Review TAB execution plan.
16. Oversee sufficient functional testing of the control system and approve it to be used for TAB, before TAB is executed.
17. Approve air and water systems balancing by spot testing, by reviewing completed reports, and by selected site observation.
18. With necessary assistance and review from installing contractors, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone data logger monitoring, or manual functional testing. Submit to CM for review and for approval, if required.
19. Analyze any functional performance trend logs and monitoring data to verify performance.
20. Coordinate, witness, and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved. Perform actual functional testing without contractors on equipment so specified in Sections 15997, 16997.
21. Maintain a master deficiency and resolution log and a separate testing record. Provide the CM with written progress reports and test results with recommended actions.
22. Witness performance testing of smoke control systems by others, and all other owner contracted tests or tests by manufacturer's personnel over which the CxA may not have direct control. Document these tests and include this documentation in Commissioning Record in O&M manuals.
23. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
24. Oversee and approve the training of the Owner's operating personnel.
25. Compile and maintain a commissioning record and building systems book(s).
26. Review and approve the preparation of the O&M manuals.
27. Provide a final commissioning report (as described in this section).

Warranty Period

1. Coordinate and supervise required seasonal or deferred testing and deficiency corrections.
2. Return to the site at 10th month into the 12-month warranty period and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.
3. Optional: Assist in the development of a preventative maintenance plan, a detailed operating plan or an energy and resource management plan or as-built documentation.

F. Construction Manager—Owner's Representative (CM)

Construction and Acceptance Phase

1. Facilitate the coordination of the commissioning work by the CxA, and, with the GC and CxA, ensure that commissioning activities are being scheduled into the master schedule.
2. Review and approve the final *Commissioning Plan—Construction Phase*.

3. Attend a commissioning scoping meeting and other commissioning team meetings.
4. Perform the normal review of Contractor submittals.
5. Furnish a copy of all construction documents, addenda, change orders, and approved submittals and shop drawings related to commissioned equipment to the CxA.
6. Review and approve the functional performance test procedures submitted by the CxA, prior to testing.
7. When necessary, observe and witness pre-functional checklists, startup and functional testing of selected equipment.
8. Review commissioning progress and deficiency reports.
9. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.
10. Sign-off (final approval) on individual commissioning tests as completed and passing. Recommend completion of the commissioning process to the Project Manager.
11. Assist the GC in coordinating the training of owner personnel.

Warranty Period

Assist the CxA as necessary in the seasonal or deferred testing and deficiency corrections required by the specifications.

G. Owner's Project Manager (PM)

Construction and Acceptance Phase

1. Manage the contract of the A/E and of the GC.
2. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions according to the *Commissioning Plan—Construction Phase*.
3. Provide final approval for the completion of the commissioning work.

Warranty Period

Ensure that any seasonal or deferred testing and any deficiency issues are addressed.

H. General Contractor (GC)

Construction and Acceptance Phase

1. Facilitate the coordination of the commissioning work by the CxA, and with the GC and CxA ensure that commissioning activities are being scheduled into the master schedule.
2. Include the cost of commissioning in the total contract price.
3. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CxA.
4. In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and training.
5. Ensure that all Subs execute their commissioning responsibilities according to the Contract Documents and schedule.
6. A representative shall attend a commissioning scoping meeting and other necessary meetings scheduled by the CxA to facilitate the Cx process.
7. Coordinate the training of owner personnel.
8. Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.

Warranty Period

1. Ensure that Subs execute seasonal or deferred functional performance testing, witnessed by the CxA, according to the specifications.
2. Ensure that Subs correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

I. Equipment Suppliers

1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner to keep warranties in force. Submittal data shall be in electronic format as .pdf files, as well as hard copy versions.
2. Assist in equipment testing per agreements with Subs.
3. Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these Contract Documents in the base bid price to the Contractor, except for stand-alone data logging equipment that may be used by the CxA.

4. Through the contractors they supply products to, analyze specified products and verify that the designer has specified the newest most updated equipment reasonable for this project's scope and budget.
 5. Provide information requested by CxA regarding equipment sequence of operation and testing procedures.
 6. Review test procedures for equipment installed by factory representatives.

1.6 DEFINITIONS

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

Approval - acceptance that a piece of equipment or system has been properly installed and is functioning in the tested modes according to the Contract Documents.

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

Basis of Design - the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The basis of design describes the systems, components, conditions, and methods chosen to meet the intent. Some reiterating of the design intent may be included.

Commissioning Authority (CxA) - an independent agent, not otherwise associated with the A/E team members or the Contractor, though he/she may be hired as a subcontractor to them. The CxA directs and coordinates the day-to-day commissioning activities. The CxA does not take an oversight role like the CM. The CxA is part of the Construction Manager (CM) team or shall report directly to the owner.

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

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

Contractor - the general contractor or authorized representative.

Control System - the central building energy management control system.

Construction Manager (CM) –

a. the Owner's representative in the day-to-day activities of construction. In general, the construction management services contractor (CM) is employed by the owner to assist in the overall management of the project including supervising and on-site managing authority over a project's construction. The General Contractor reports to the CM. The CM is the Owner's representative.

b. When the CxA is hired by the GC or A/E, the CM referred to in the commissioning process is a member of the CM team (staff or independent contractor) who shall have direct significant mechanical engineering and commissioning experience. That person designated from the CM team is the owner's representative verifying the adequacy of the commissioning process. In this case, the CM will be more involved in the commissioning work and in witnessing portions of the process (selected start-up and functional tests) and reviewing documents (test approvals, etc.) than in the following case.

c. When the CxA is hired by the CM (on staff or as a subcontractor), or directly by the Owner, there may not need to be another CM representative reviewing and approving the work of the CxA, other than schedule approvals and consultation during problem solving. In that case, references to the CM in these *Specifications* would actually mean the CxA, except that CxA progress reports would go to the PM rather than the CM.

Data logging - monitoring flows, currents, status, pressures, etc. of equipment using stand-alone

data loggers separate from the control system.

Deferred Functional Tests – Functional Tests that are performed later, after substantial completion, due to partial occupancy, equipment, seasonal requirements, design, or other site conditions that disallow the test from being performed.

Deficiency - a condition in the installation or function of a component, piece of equipment or system that is not in compliance with the Contract Documents (that is, does not perform properly or is not complying with the design intent).

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

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

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

Functional Performance Test (FT) - test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Functional testing is the dynamic testing of systems (rather than just components) under full operation (e.g., the chiller pump is tested interactively with the chiller functions to see if the pump ramps up and down to maintain the differential pressure setpoint). Systems are tested under various modes such as: during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, etc. The systems are run through all the control system's sequences of operation and components are verified to be responding as the sequences state. Traditional air or water test and balancing (TAB) is not functional testing, in the commissioning sense of the word. TAB's primary work is setting up the system flows and pressures as specified, while functional testing is verifying that which has already been set up. The commissioning authority develops the functional test procedures in a sequential written form, coordinates, oversees, and documents the actual testing which is usually performed by the installing contractor or vendor. Functional tests are performed after pre-functional checklists and startup are complete.

General Contractor (GC) - the prime contractor for this project. Generally refers to all the GC's subcontractors as well. (Also referred to as the Contractor in some contexts).

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

Manual Test - using hand-held instruments, immediate control system readouts, or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the "observation").

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

Non-Compliance - see Deficiency.

Non-Conformance - see Deficiency.

Over-written Value - writing over a sensor value in the control system to see the response of a system (e.g., changing the outside air temperature value from 50F to 75F to verify economizer operation). See also "Simulated Signal."

Owner-Contracted Tests - tests paid for by the Owner outside the GC's contract and for which the CxA does not oversee. These tests will not be repeated during functional tests, if properly documented.

Phased Commissioning - commissioning that is completed in phases (by floors, for example) due to the size of the structure or other scheduling issues, in order minimize the total construction time.

Pre-functional Checklist (PC) - a list of items to inspect and elementary component tests to conduct, to verify proper installation of equipment provided by the CxA to the Sub. Pre-functional checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels OK, labels affixed, gages in place, sensors calibrated, etc.). However, some pre-functional checklist items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a three phase pump motor of a chiller system). The word pre-functional refers to before functional testing. Pre-functional checklists augment and are combined with the manufacturer's start-up checklist. Even without a commissioning process, contractors typically perform some, if not many of the pre-functional checklist items a commissioning authority will recommend. However, few contractors document in writing the execution of these checklist items. Therefore, for most equipment, the contractors execute the checklists on their own. The commissioning authority only requires that the procedures be documented in writing and does not witness much of the pre-functional testing, except for larger or more critical pieces of equipment.

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

Sampling - functionally testing only a fraction of the total number of identical or near identical pieces of equipment. Refer to Section 17100, Part 3.6, for details.

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

Simulated Condition - condition that is created for the purpose of testing the response of a system (e.g., applying a hair blower to a space sensor to see the response in a VAV box).

Simulated Signal - disconnecting a sensor and using a signal generator to send an amperage, resistance, or pressure to the transducer and DDC system to simulate a sensor value.

Specifications - the construction specifications of the Contract Documents.

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

Subs - the subcontractors to the GC who provide and install building components and systems.

Test Procedures - the step-by-step process which must be executed to fulfill the test requirements. The CxA develops the test procedures.

Test Requirements - requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures. The test requirements are specified in the Contract Documents (Sections 15997, 16997).

Trending - monitoring using the building control system.

Vendor - supplier of equipment.

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

1.7 SYSTEMS TO BE COMMISSIONED

A. The following checked systems will be commissioned in this project.

Equipment and System	Functional Test Requirements Specified In:	Equipment and System	Functional Test Requirements Specified In:
<u>HVAC System</u>	15997	Equipment vibration control	15997
Pumps	15997		
Piping systems	15997		
		<u>Electrical System</u>	
Ductwork	15997	Sweep or scheduled lighting controls	16997
Variable frequency drives	15997	Daylight dimming controls	16997
Air handlers	15997	Lighting occupancy sensors	16997
Terminal units (air)	15997	Power quality	16997
Computer room units	15997	Emergency power system	16997
Specialty fans	15997	UPS systems	16997
Testing, Adjusting, and Balancing work	15997	Fire and smoke alarm	16997
Chemical treatment systems	15997	Fire protection systems	16997
HVAC control system	15997	Communications system	16997
Fire and smoke dampers	15997	Public address/paging	16997
Indoor air quality ¹ by CxA	15997		
Equipment sound control	15997		
Building automation system (controlled devices, control loops & system integration)	15997		
		<u>Other</u>	
Service water heaters	15997		

¹ Indoor air quality (IAQ) commissioning does not ensure that indoor air quality will be adequate or without deficiency at building turnover or during occupancy, unless the owner has specifically specified that actual air quality testing is performed. Commissioning indoor air quality entails performing tasks that minimize the potential for IAQ problems, but it does not eliminate their possibility.

2.1 TEST EQUIPMENT

- A. All standard testing equipment required to perform startup and initial checkout and required functional performance testing shall be provided by the Division contractor for the equipment being tested. For example: the mechanical contractor of Division 15 shall ultimately be responsible for all standard testing equipment for the HVAC system and controls system in Division 15, except for equipment specific to and used by TAB in their commissioning responsibilities.
- B. Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents shall be included in the base bid price to the Contractor and left on site, except for stand-alone data logging equipment that may be used by the CxA.
- C. Data logging equipment and software required to test equipment will be provided by the CxA, but shall not become the property of the Owner.
- D. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the *Specifications*. If not otherwise noted, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration within the past year to an accuracy of 0.5°F and a resolution of + or - 0.1°F. Pressure sensors shall have an accuracy of + or - 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year. All equipment shall be calibrated according to the manufacturer's recommended intervals, and when dropped or damaged. Calibration tags shall be affixed or certificates readily available.
- E. Refer to Section 17100, Part 3.6 (E) for details regarding equipment that may be required to simulate required test conditions.

3.1 MEETINGS

- A. Scoping Meeting. Scoping meeting will be held within 30 days of contract award days of commencement of construction. The CxA will schedule, plan, and conduct a commissioning scoping meeting with the entire commissioning team in attendance. Meeting minutes will be distributed to all parties by the CxA. Information gathered from this meeting will allow the CxA to revise the *Commissioning Plan* to its "final" version which will also be distributed to all parties.
- B. Miscellaneous Meetings. Other meetings will be planned and conducted by the CxA as construction progresses. These meetings will cover coordination, deficiency resolution, and planning issues with particular Subs. The CxA will plan these meetings and will minimize unnecessary time being spent by Subs. For large projects, these meetings may be held monthly until the final 3 months of construction when they may be held as frequently as one per week.

3.2 REPORTING

- A. The CxA will provide regular reports to the CM or PM, depending on the management structure, with increasing frequency as construction and commissioning progress. Standard forms are provided and referenced in the *Commissioning Plan*.
- B. The CxA will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.
- C. Testing or review approvals and non-conformance and deficiency reports are made regularly with the review and testing as described in later sections.

D. A final summary report (about four to six pages, not including backup documentation) by the CxA will be provided to the CM or PM, focusing on evaluating commissioning process issues and identifying areas where the process could be improved. All acquired documentation, logs, minutes, reports, deficiency lists, communications, findings, unresolved issues, etc., will be compiled in appendices and provided with the summary report. Pre-functional checklists, functional tests and monitoring reports will not be part of the final report, but will be stored in the Commissioning Record in the O&M manuals.

3.3 SUBMITTALS

A. The CxA will provide appropriate contractors with a specific request for the type of submittal documentation the CxA requires, facilitating the commissioning work. These requests will be integrated into the normal submittal process and protocol of the construction team. At minimum, the request will include the manufacturer and model number, the manufacturer's printed installation and detailed start-up procedures, full sequences of operation, O&M data, performance data, any performance test procedures, control drawings, and details of owner contracted tests. In addition, the installation and checkout materials that are actually 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. All documentation requested by the CxA will be included by the Subs in their O&M manual contributions. Electronic format, (*on compact disc or Digital Video Disc (DVD) .pdf*), submittals are required, as well as hard copy versions.

B. The CxA will review and approve submittals related to the commissioned equipment for conformance with the Contract Documents as it relates to the commissioning process, to the functional performance of the equipment, and to adequacy for developing test procedures. This review is intended primarily to aid in the development of functional testing procedures and only secondarily to verify compliance with equipment specifications. The Commissioning authority will notify the CM, PM, or A/E as requested, of items missing or areas that are not in conformance with Contract Documents and which will require resubmission.

C. The CxA may request additional design narrative from the A/E and Controls Contractor, depending on the completeness of the design intent documentation and sequences provided with the Specifications.

D. These submittals to the CxA do not constitute compliance for O&M manual documentation. The O&M manuals are the responsibility of the Contractor, though the CxA will review and approve them.

3.4 START-UP, PREFUNCTIONAL CHECKLISTS, AND INITIAL CHECKOUT

A. The following procedures apply to all equipment to be commissioned, according to Section 1.7, "Systems to be Commissioned." Some systems that are not comprised so much of actual dynamic machinery (e.g.: electrical system power quality), may have very simplified PCs and startup.

B. General. Pre-functional checklists are important to ensure that the equipment and systems are hooked up and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full pre-functional checkout. No sampling strategies are used. The pre-functional testing for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.

C. Start-up and Initial Checkout Plan. The CxA shall assist the commissioning team members responsible for startup of any equipment in developing detailed start-up plans for all equipment. The primary role of the CxA in this process is to ensure that there is written documentation that each of the manufacturer-recommended procedures have been completed. Parties responsible for pre-functional checklists and startup are identified in the commissioning scoping meeting and in the checklist forms. Parties responsible for executing functional performance tests are identified in the testing requirements in Sections 15997, 16997.

1. The CxA adapts, if necessary, the representative pre-functional checklists and procedures from Section 15997. These checklists indicate required procedures to be executed as part of startup and initial checkout of the systems, and the party responsible for their execution.

2. These checklists and tests are provided by the CxA to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.

3. The subcontractor responsible for the purchase of the equipment develops the full start-up plan by combining (or adding to) the CxA's checklists with the manufacturer's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure, and a summary statement with a signature block at the end of the plan.

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

a. The CxA copies the manufacturer's startup and initial checkout procedures from O&M submittals.

b. The CxA marks the applicable areas in the procedures and makes initial and date lines at each procedure or section.

c. The CxA transmits these procedures and the original pre-functional checklist procedures (see 1 above) to the Contractor as the startup and initial checkout plan.

4. The subcontractor submits the full startup plan to the CxA for review and approval.

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

6. The full start-up procedures and the approval form may be provided to the CM for review and approval, depending on management protocol.

D. Sensor and Actuator Calibration. All field-installed temperature, relative humidity, CO, CO₂, and pressure sensors and gages, and all actuators (dampers and valves) on all equipment shall be calibrated using the methods described below. Alternate methods may be used, if approved by the Owner before hand. All test instruments shall have had a certified calibration within the last 12 months. Sensors installed *in* the unit at the factory with calibration certification.

All procedures used shall be fully documented on the pre-functional checklists or other suitable forms, clearly referencing the procedures followed and written documentation of initial, intermediate and final results.

Sensor Calibration Methods.

All Sensors - Verify that all sensor locations are appropriate and away from causes of erratic operation. Verify that sensors with shielded cable are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading, of each other, for pressure. Tolerances for critical applications may be tighter.

Sensors Without Transmitters - Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or Building Automation System (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.

Sensors With Transmitters - Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until the ammeter reads 4 mA. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform to specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

Critical Applications - For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

Tolerances, Standard Applications

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

Valve and Damper Stroke Setup and Check

EMS Readout - For all valve and damper actuator positions checked, verify the actual position against the BAS readout.

Set pumps or fans to normal operating mode. Command valve or damper closed, visually verify that valve or damper is closed and adjust output zero signal as required. Command valve or damper open, verify position is full open and adjust output signal as required. Command valve or damper, adjust to a few intermediate positions. If actual valve or damper position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics).

Closure for heating coil valves (NO) - Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. For pneumatics, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

Closure for cooling coil valves (NC) - Set cooling setpoint 20°F above room temperature. Observe the valve close. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set cooling setpoint to 20°F below room temperature. Observe valve open. For pneumatics, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

E. Execution of Pre-functional Checklists and Startup.

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

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

3. For lower-level components of equipment, (e.g., VAV boxes, sensors, controllers), the CxA shall observe a sampling of the pre-functional and start-up procedures. The sampling procedures are identified in the commissioning plan.

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

5. Only individuals that have direct knowledge and witnessed that a line item task on the pre-functional checklist was actually performed shall initial or check that item off. It is not acceptable for witnessing supervisors to fill out these forms.

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

1. The Subs shall clearly list any outstanding items of the initial start-up and pre-functional procedures that were not completed successfully, at the bottom of the procedures form or on an attached sheet. The procedures form and any outstanding deficiencies are provided to the CxA within two days of test completion.

2. The CxA reviews the report and submits either a non-compliance report or an approval form to the Sub or CM. The CxA shall work with the Subs and vendors to correct and retest deficiencies or uncompleted items. The CxA will involve the CM and others as necessary. The installing Subs or vendors shall correct all areas that are deficient or incomplete in the checklists and tests, in a timely manner, shall notify the CxA as soon as outstanding items have been corrected, and resubmit an updated start-up report and a Statement of Correction on the original non-compliance report. When satisfactorily completed, the CxA recommends approval of the execution of the checklists and startup of each system to the CM using a standard form.

3. Items left incomplete, which later cause deficiencies or delays during functional testing may result in back charges to the responsible party. Refer to Part 3.7 herein for details.

3.5 PHASED COMMISSIONING

The project ___ will require, or ___ will *not* require startup and initial checkout to be executed in phases. This phasing will be planned and scheduled in a coordination meeting of the CxA, CM, mechanical, TAB controls, and the GC. Results will be added to the master and commissioning schedule.

3.6 FUNCTIONAL PERFORMANCE TESTING

- A. This sub-section applies to all commissioning functional testing for all divisions.
- B. The general list of equipment to be commissioned is found in Section 17100 Part 1.7. The specific equipment and modes to be tested are found in Sections 15997, 16997.
- C. The parties responsible to execute each test are listed with each test in Sections 15997, 16997.
- E. Objectives and Scope. The objective of functional performance testing is to demonstrate that each system is operating according to the documented design intent and Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems.
- F. In general, each system should be operated through all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested. Specific modes required in this project are given in Sections 15997, 16997.
- G. Development of Test Procedures. Before test procedures are written, the CxA shall obtain all requested documentation and a current list of change orders affecting equipment or systems, including an updated points list, program code, control sequences, and parameters using the testing parameters and requirements in Sections 15997, 16997. The CxA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each Subcontractor or vendor responsible to execute a test shall provide limited assistance to the CxA in developing the procedures review (answering questions about equipment, operation, sequences, etc.). Prior to execution, the CxA shall provide a copy of the test procedures to the Subcontractors who shall review the tests for feasibility, safety, equipment and warranty protection. The CxA may submit the tests to the A/E for review, if requested.

The CxA shall review owner-contracted, factory testing or required owner acceptance tests which the CxA is not responsible to oversee, including documentation format, and shall determine what further testing or format changes may be required to comply with the *Specifications*. Redundancy of testing shall be minimized.

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

The test procedure forms developed by the CxA shall include (but not be limited to) the following information:

1. System and equipment or component name(s)
2. Equipment location and ID number
3. Date
4. Project name
5. Participating parties
6. A copy of the specific sequence of operations or other specified parameters being verified
7. Formulas used in any calculations
8. Required pre-test field measurements
9. Special cautions, alarm limits, etc.
10. Acceptance criteria of proper performance with a Yes / No check box to allow for clearly marking whether or not proper performance of each part of the test was achieved.
11. A section for comments

12. Signatures and date block for the CxA

F. Test Methods.

1. Functional performance testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone data loggers. Sections 15997, 16997: The CxA may substitute specified methods or require an additional method to be executed, other than what was specified, with the approval of the CM. This may require a change order and adjustment in charge to the Owner. The CxA will determine which method is most appropriate for tests that do not have a method specified.
2. Simulated Conditions - Simulating conditions shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
3. Overwritten Values - Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable. e.g.: for the above case, by heating the outside air sensor with a hair blower rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers, and devices shall have been calibrated.
4. Simulated Signals - Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.
5. Altering Setpoints - Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example: to see the AC compressor lockout work at an outside air temperature below 55F, when the outside air temperature is above 55F, temporarily change the lockout setpoint to be 2F above the current outside air temperature.
6. Indirect Indicators - Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification is completed during pre-functional testing.
7. Setup - Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Sub executing the test shall provide all necessary materials, system modifications, etc., to produce the necessary flows, pressures, temperatures, etc., necessary to execute the test according to the specified conditions. At completion of the test, the Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.
8. Sampling - Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. Significant application differences and significant sequence of operation differences in otherwise identical equipment invalidates their common identity. A small size or capacity difference, alone, does not constitute a difference. The specific recommended sampling rates are specified with each type of equipment in Sections 15997, 16997. It is noted that no sampling by Subs is allowed in pre-functional checklist execution.

A common sampling strategy referenced in the *Specifications* as the "xx% Sampling—yy% Failure Rule" is defined by the following example.

xx = the percent of the group of identical equipment to be included in each sample.

to be tested.

yy = the percent of the sample that if failing, will require another sample

The example below describes a 20% Sampling—10% Failure Rule.

- a. Randomly test at least 20% (xx) of each group of identical equipment. In no case test less than three units in each group. This 20%, or three, constitute the "first sample."
- b. If 10% (yy) of the units in the first sample fail the functional performance tests, test another 20% of the group (the second sample).
- c. If 10% of the units in the second sample fail, test all remaining units in the whole group.
- d. *If at any point, frequent failures are occurring and testing is becoming more troubleshooting than verification, the CxA may stop the testing and require the responsible subcontractor to perform and document a checkout of the remaining units, prior to continuing with functionally testing the remaining units.*

G. Coordination and Scheduling - The Subs shall provide sufficient notice to the CxA regarding their completion schedule for the pre-functional checklists and startup of all equipment and systems. The CxA will schedule functional tests through the CM, GC, and affected Subs. The CxA shall direct, witness and document the functional testing of all equipment and systems. The Subs shall execute the tests.

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

H. Test Equipment - Refer to Section 17100, Part 2 for test equipment requirements.

I. Problem Solving - The CxA will recommend solutions to problems found. However, the burden of responsibility to solve, correct, and retest problems is with the GC, Subs, and A/E.

3.7 DOCUMENTATION, NON-CONFORMANCE, AND APPROVAL OF TESTS

A. Documentation - The CxA shall witness and document the results of all functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the CM for review and approval, and to the Subs for review. The CxA will include the filled out forms in the O&M manuals.

B. Non-Conformance

1. The CxA will record the results of the functional test on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the CM.
2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the CxA.
 3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the CxA will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so at the request of the CM.

4. As tests progress and a deficiency is identified, the CxA discusses the issue with the executing contractor.

a. When there is no dispute on the deficiency and the Sub accepts responsibility to correct it:

1. The CxA documents the deficiency and the Sub's response and intentions and they go on to another test or sequence.
2. The Sub corrects the deficiency and notifies the CxA the equipment is ready for testing.
3. The CxA reschedules the test and the test is repeated.

b. If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible:

1. The deficiency shall be documented with the Sub's response and a copy given to the CM and to the Sub representative assumed to be responsible.
2. Resolutions are made at the lowest management level possible. Other parties are brought into the discussions as needed. Final interpretive authority is with the A/E. Final acceptance authority is with the Project Manager.
3. The CxA documents the resolution process.
4. Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the statement of correction on the non-compliance form, and provides it to the CxA. The CxA reschedules the test and the test is repeated until satisfactory performance is achieved.

5. Cost of Retesting

a. The cost for the *Sub* to retest a pre-functional or functional test, if they are responsible for the deficiency, shall be theirs. If they are not responsible, any cost recovery for retesting costs shall be negotiated with the GC.

b. For a deficiency identified, not related to any pre-functional checklist or start-up fault, the following shall apply: The CxA and CM will direct the retesting of the equipment once at no "charge" to the GC for their time. However, the CxA's and CM's time for a second retest will be charged to the GC, who may choose to recover costs from the responsible Sub.

c. The time for the CxA and CM to direct any retesting required because a specific *pre-functional* checklist or start-up test item, reported to have been successfully completed, but determined during functional testing to be faulty, will be back charged to the GC, who may choose to recover costs from the party responsible for executing the faulty pre-functional test.

d. Refer to the sampling section of Section 17100, Part 3.6 for requirements for testing and retesting identical equipment.

6. The Contractor shall respond, in writing, to the CxA and CM, at least as often as commissioning meetings are being scheduled, concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.

7. The prime contractor shall not consider any required retesting by any contractor, a justified reason for a claim of delay or for a time extension.

C. Failure Due to Manufacturer Defect - If 10%, or three, whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively), due to manufacturing defect, not allowing it to meet its submitted performance spec, all identical units may be considered unacceptable by the CM or PM. In such case the Contractor shall provide the Owner with the following:

1. Within one week of notification from the CM or PM, the Contractor or manufacturer's representative shall examine all other identical units making a record of the findings. The findings shall be provided to the CM or PM within two weeks of the original notice.

2. Within two weeks of the original notification, the Contractor or manufacturer shall provide a signed and dated, written explanation of the problem, cause of failures, etc., and all proposed solutions which shall include full equipment submittals. The proposed solutions shall not significantly exceed the specification requirements of the original installation.

3. The CM or PM will determine whether a replacement of all identical units or a repair is acceptable.

4. Two examples of the proposed solution will be installed by the Contractor and the CM will be allowed to test the installations for up to one week, upon which the CM or PM will decide whether to accept the solution.

5. Upon acceptance, the Contractor and/or manufacturer shall replace or repair all identical items, at their expense, and extend the warranty accordingly, if the original equipment warranty had begun. The replacement/repair work shall proceed with reasonable speed beginning within one week from when parts can be obtained.

D. Approval - The CxA notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made later after review by the CxA and by the CM, if necessary. The CxA recommends acceptance of each test to the CM using a standard form. The CM gives final approval on each test using the same form, providing a signed copy to the CxA and the Contractor.

3.8 OPERATION AND MAINTENANCE MANUALS

A. Standard O&M Manuals

1. The specific content and format requirements for the standard O&M manuals are detailed in Section 01730. Special requirements for the controls contractor and TAB contractor are found Section 15995, Part 3.6.

2. A/E Contribution - The A/E will include in the beginning of the *Commissioning Manual*, a separate section describing the systems including the design intent narrative prepared by the A/E and provided as part of the bid documents, updated to as-built status by the A/E.

3. CxA Review and Approval - Prior to substantial completion, the CxA shall review the O&M manuals, documentation, and redline as-builts *for systems that were commissioned* and to verify compliance with the *Specifications*. The CxA will communicate deficiencies in the manuals to the CM, PM, or A/E, as requested. Upon a successful review of the corrections, the CxA recommends approval and acceptance of these sections of the O&M manuals to the CM, PM, or A/E. The CxA also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated. This work does not supersede the A/E's review of the O&M manuals according to the A/E's contract.

B. Commissioning Record in Commissioning Manual

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

Tab 1	Design Intent and Mechanical and Electrical design narratives
Tab 2	Commissioning Specification
Tab 3	Commissioning Plan
Tab 4	Review Comments
Tab 5	Inspection Reports/Inspection Pictures
Tab 6	Test Reports
Tab 7	Final Commissioning Report
Tab 8	Lessons Learned Report
Tab 9	Meeting Minutes
Tab 10	LEED Information (when applicable)

3.9 TRAINING OF OWNER PERSONNEL

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

1. The CxA shall interview the facility manager and lead engineer to determine the special needs and areas where training will be most valuable. The Owner and CxA shall decide how rigorous the training should be for each piece of commissioned equipment. The CxA shall communicate the results to the Subs and vendors who have training responsibilities.
2. Each Subcontractor and vendor responsible for training will submit a written plan to the CxA for review and approval prior to training. The plan will cover the following elements of training:
 - a. Equipment (included in training)
 - b. Intended audience
 - c. Location of training
 - d. Objectives
 - e. Methods (classroom lecture, video, site walk through, on site demonstration, etc.)
 - f. Duration of training period
 - g. Subjects covered
 - h. Instructor

B. The CxA develops an overall training plan and coordinates and schedules, with the CM and GC, the overall training for the commissioned systems. The CxA develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The CxA recommends approval of the training to the CM using a standard form. The CM also signs the approval form.

C. The CxA develops an overall training plan and coordinates and schedules, with the CM and GC, the overall training for the commissioned systems. The CxA develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The CxA recommends approval of the training to the CM using a standard form. The CM also signs the approval form.

D. The CxA develops an overall training plan and coordinates and schedules, with the CM and GC, the overall training for the commissioned systems. The CxA develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The CxA

recommends approval of the training to the CM using a standard form. The CM also signs the approval form.

3.10 DEFERRED TESTING

A. Unforeseen Deferred Tests – If any check or test cannot be completed due to the building structure, required occupancy condition, or other deficiency, execution of checklists and functional testing may be delayed upon approval of the PM. These tests will be conducted in the same manner as the seasonal tests, as soon as possible. Services of necessary parties will be negotiated.

B. Seasonal Testing – During the warranty period, seasonal testing, (tests delayed until weather conditions are closer to the system’s design) specified in Section 15997 shall be completed as part of this contract. The CxA shall coordinate this activity. Tests will be executed, documented, and deficiencies corrected by the appropriate Subs, with facilities staff and the CxA witnessing. Any final adjustments to the O&M manuals and as-builds due to the testing will be made.

3.11 WRITTEN WORK PRODUCTS

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

	<u>Product</u>	<u>Developed By</u>
	1. Final commissioning plan	CxA
	2. Meeting minutes	CxA
	3. Commissioning schedules	CxA with GC and CM
	4. Equipment documentation submittals	Subs
	5. Sequence clarifications	Subs and A/E as needed
	6. Pre-functional checklists	CxA
	7. Startup and initial checkout plan	Subs and CxA (compilation of existing documents)
	8. Startup and initial checkout forms filled out	Subs
	9. Final TAB report	TAB
	10. Issues log (deficiencies)	CxA
	11. Commissioning Progress Record	CxA
	12. Inspection reports	CxA
	13. Functional test forms	CxA
	14. Filled out functional tests	CxA
	15. O&M manuals	Subs
	16. Commissioning manual	CxA
	17. Overall training plan	CxA and CM
	18. Specific training agendas	Subs
	19. Final commissioning report	CxA

END OF SPECIFICATION SECTION