
Cx Integration Plan

Version 1.0

Spelman College Residence Housing Project

AEI Project Number: 06581-00

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--- Commissioning Integration Plan ---

Project Overview

The project consists of a 300 bed residence hall, a dining hall with a 175 seating capacity, several apartments for visiting faculty and trustees, and inside parking for 100 automobiles. Designed to compliment the other campus structures, the project also creates a new campus open space that is related to the rest of the campus and its historic quadrangle.

Scheduled completion - May, 2008

Commissioning Team (CxT)

The commissioning (Cx) process includes participation by the entire project delivery team. Contact information for the project team members can be found in the project directory.

Owner – Spelman College

Design Professional (A/E)

Architect – Facility Design Group, Inc.

Mechanical Electrical Piping Engineer – Facility Design Group, Inc.

Program Manager

Brookwood Program Management

Builder

New South Construction Co.

Sub-contractors

Schumate Mechanical. - Mechanical Contractor (MC)

Fitzgerald Plumbing. - Piping/ Plumbing Contractor (PC)

Inglett & Stubbs, Inc. - Electrical Contractor (EC)

WJE - Test Adjust Balance Contractor (TAB)

Siemens Building Technologies - Controls Contractor (CC)

Cx Provider (CxP)

Mechanical Electrical Piping (MEP) – Affiliated Engineers, Inc.

Building Envelope – Stafford Consulting Engineers

Roles Responsibilities and Protocol

General Management Plan

The CxP coordinates the Cx activities with Brookwood Program Management and reports to Spelman College. The A/E, Builder and CxP all contribute to the project as stipulated in their respective contracts. The Contract Documents take precedence over this Cx Plan.

Team Members

Members of the project team participating in Cx activities include Spelman College, Brookwood the CxP, A/E, Builder, MC, EC, TAB, CC and any other installing sub-contractors or equipment suppliers whose scope includes system included in the scope of Cx.

Spelman

- Spelman & Brookwood will approve all aspects of the Cx plan and specification development.
- Brookwood will coordinate official documentation exchanges between the A/E, Builder and CxP.

A/E

- Be responsible for the building systems design.
- Provide comprehensive design information in the form of a basis of design, a design narrative, construction plan drawings and construction specifications required for Cx review of design documents.
- Be responsible for contract document corrections as directed by the Cx Team through Brookwood.
- Witness Cx activities as required to assist in clarifying operating sequences or parameters.
- Provide construction phase observation independent of the Cx activities. Cx observation does not replace the efforts of the design team.
- Participate in owner orientation as appropriate.

Builder

- Incorporate the tasks and scheduling requirements of the Cx process into the Construction Schedule.
- Provide approved shop drawings and O&M Manuals to CxP for all systems to be commissioned.
- Forward all required startup and prefunctional checklists to CxP prior to the scheduled start of Functional Performance Testing (FPT).
- Coordinate the scheduling of all Sub-contractors and Manufacturers Representatives with CxP for all inspections, training sessions, and tests performed during the Cx process.
- Be responsible to facilitate timely conflict resolution or system modifications and re-schedule subsequent retesting as required.
- Be responsible for scheduling, developing, performing and documenting point-to-point check out and calibration of all mechanical and electrical systems.

Sub-contractors (ME, EE, CC, TAB, Etcetera)

- Be responsible for system installation in accordance with the contract documents.
- Be responsible for completing all required documentation as specified.

- Provide all equipment, tools, materials, and qualified personnel required to complete functional performance tests. That is, the sub-contractor will demonstrate comprehensive system functionality to the Cx team.
- Make needed repairs, calibrations, and adjustments to bring systems up to full acceptance levels.
- Solicit cooperation from equipment vendors for the purpose of training Spelman's Maintenance Staff and the user staff where specified, in order to fulfill the specified training program.
- Provide the individual of greatest field authority and most familiarity with the respective system as the representative to the Cx Team.

CxP

- Conduct and document each step of the Cx process and recommend acceptance or non-acceptance to Spelman and Brookwood. CxP will identify conflicts, deficiencies, additions, modifications, and/or corrections required at each step and participate in the coordination and resolution of all issues.
- Review all narrative, schematic, design development, and construction documents prepared by the A/E. Document review will provide critique of building system design, ensure consistency with Spelman's goals and objectives, and ensure system commissionability.
- Develop the Cx plan and Cx specification.
- Review shop drawings and O&M Manuals to verify that systems and equipment submitted are consistent with the Cx plan. The Cx specifications will require the shop drawings be submitted in an organized/grouped basis to ensure a limited/consolidated review period.
- Develop prefunctional checklists and conduct and document installation verification observations.
- Develop and witness functional performance tests (FPT) for all commissioned systems.
- Oversee coordination of training of operations and maintenance personnel.
- Coordinate collection and review of final O&M material for commissioned systems.

Cx Process Overview

Overview of Cx

The Cx process on this project is intended to be a systematic process of ensuring that building systems perform interactively according to the design intent and Spelman's operational needs. We began during the design phase with documented design and operating intent and are continuing through the construction and acceptance phases with actual verification of system performance.

Overview of Cx during Design

The commissioning process for this project began early in the design phase. During the design phase we:

- Provide Cx focused design reviews.

- Ensure that Cx activities for the construction phase were adequately reflected in the bid documents so that Cx could be considered during the bid process.
- Develop verification and testing documentation which is coordinated with the design intent and design documents.
- Develop a construction phase Cx plan.

Overview of Cx during Construction and Acceptance

The CxP will participate in construction site observation. This site review will primarily be to monitor:

- Quality of installation,
- Conformance with specification requirements and design intent, and
- Commission-ability as installed.

As systems become complete through the course of construction, the sub-contractors will alert the team when the Prefunctional Checklist and all manufacturers' required start-up documentation are complete. Following review of the documentation, possibly in the field, Spelman, Brookwood, A/E and CxP will make a recommendation to proceed with functional testing. Issues identified during construction or during the execution of functional testing will be posted to a master Cx Action List. Resolved issues will be revisited by the originator prior to removal from the issues list.

O&M manuals and training plans are submitted to the design and Cx team for review and "enhancement". Training is then given to users and facility personnel by sub-contractors using approved O&M documentation as a basis.

Cx / Construction Sequence

CxP shall coordinate with Brookwood and the Builder to incorporate Cx activities into the construction schedule. The minimum following milestones will be integrated into the construction schedule:

1. Start date for each Sub-contractor
2. Submission of product and activity submittals as specified in contract documents.
3. Incorporation of submitted information into FPT procedures.
4. Construct specified mock-ups for building envelope systems
5. Construct specified mock-ups for cleanroom systems
6. Issue final FPT's
7. Observe Acceptance Tests at various phases of construction (i.e.; Pressure Testing for each system as specified)
8. Start-up
9. Submission of O&M documentation for each system.
10. Training plan submission for each system
11. Point to Point checkout
12. Test Adjust Balance
13. Prefunctional Checklist completion
14. Prefunctional Checklist verification and consolidation for each system by Builder
15. Prefunctional Checklist verification by CxP and Brookwood
16. FPT
17. Training
18. Warranty review

Systems

The following systems are included in the Cx scope per the original project fact sheet Cx services solicitation.

HVAC

- Campus chilled and heating water entrance
- Four-pipe chilled water and heating water fan-coil system - housing area suites, Associated kitchen, dining and visitors housing utilizing a 25% sampling strategy
- Air handling units w/VAV distribution - kitchen, cafeteria and other large public areas
- Energy recovery units
- Mechanical and electrical space ventilation
- Toilet/ laundry exhaust
- HVAC controls - Digital Siemens Building Technology

Electrical

- Pad mounted primary transformer
- Primary line conductors, secondary line conductors
- Two main service entrance switchboards
- Main compartment digital meter
- Main compartment transient voltage surge suppression system
- Skid-mounted standby emergency generator, metering, and automatic transfer switches
- Distribution, lighting and receptacle panelboards (25% sampling strategy will be employed)
- Individual dormitory suite load centers (25% sampling strategy will be employed)
- Individual guest suite load centers
- Grounding
- Lightning protection
- Timer-controlled public-area lighting control system
- Addressable class B, supervised, non-coded, multi- zone fire alarm system
- Interior telecommunication, door security, card reader, CCTV, CATV raceway systems testing/ verification by others.

Plumbing/ Fire Protection:

- The domestic water services including booster pump and backflow prevention
- Domestic hot and cold water - suites and laundry areas
- Domestic hot and cold water - kitchen.
- Sanitary and storm piping
- Kitchen waste - safe waste system with a grease trap
- Fire protection water including backflow prevention, meters, fire pump, jockey pump and stand pipe.

Building Envelope:

Exterior wall cladding

Primary roof system

Cx Process – Construction Phase

MEP Cx Kickoff Meeting

A Cx kickoff meeting is planned and conducted by the Cx Team early in the construction process. Representatives of Spelman, Brookwood, the Design Team, the Cx Team, the Builder and the mechanical, electrical, controls, and TAB sub-contractors are required to attend. The Cx process is reviewed and management and reporting lines are defined. Questions about the Cx process are addressed along with a review of each party's responsibilities. The intended outcome of the meeting is an increased understanding by all parties of the Cx process and their respective responsibilities.

Building Envelope Cx Kickoff Meeting

A Cx kickoff meeting which focuses on the building envelope systems will be held in tandem with the MEP Cx Kickoff meeting. The object will be to discuss testing which will occur throughout the construction process as well as expectations for each element of the testing process. The team will discuss scheduling regarding site visits and testing. All sub-contractors whose scope includes building envelope or related tasks will be required to attend.

Cx - Construction Phase Scheduling

Cx activities will be integrated into the project construction schedule. The Builder will be responsible for submitting a proposed schedule as required in the general conditions. The Cx specification will list specific line items to be incorporated into the construction schedule such that these activities are in integral component to the construction process.

Site Observation

The Cx Team makes periodic visits to the site, as necessary, to witness equipment and system installations. These visits do not replace the efforts of the Design Team and the Design Team should visit the project site as required.

Construction Meetings

The Cx Team attends various planning and job-site meetings in order to remain informed on construction progress and to update parties involved in Cx. Coordination between the Cx and Construction Team will occur such that Cx related issues are included on the agenda so proper preparation by all may be made.

Cx Meetings

The Cx Team will hold a dedicated job-site Cx meeting in order to address Cx activities as they relate to the construction of the project. Meeting notes will be issued and will include outcome of the meetings as well as responsibilities of attendees that are a result of the meeting.

Management Protocols

The following protocols will be used on this project.

<u>Issue</u>	<u>Protocol</u>
Minor or verbal information and clarifications.	Cx Team representative goes directly to informed party.
Notifying sub-contractors of deficiencies.	Cx Team representative provides written documentation to Spelman, Brookwood, the Builder and the A/E
Scheduling functional tests or training.	Cx Team representative coordinates with Builder.
Making a request for significant changes.	Cx Team representative makes request through A/E, with a copy to Spelman and Brookwood.
Sub-contractors disagreeing with requests or interpretations by Cx Team.	Try to resolve with Cx Team first. Then work through Builder who will work with Cx Team directly or through the Builder to resolve the situation.

Execution of Prefunctional Checklists and Startup

Prior to actual startup, the Builder schedules startup and initial checkout with Cx team. Sub-contractors execute initial startup and checkout. Cx team members reserve the right to observe startup procedures for each piece of equipment or system. Sub-contractor responsible for startup will document the process by initialing and dating each line item of the respective prefunctional checklist as activities are completed. The prefunctional checklist and any additional manufacturer's start-up documentation are to be completely completed and submitted prior to startup of a piece of equipment or system. Only individuals having direct knowledge of line item being completed shall check or initial forms.

Following the completion and submission of the prefunctional checklist by the installing sub-contractor, the Builder collects all prefunctional checklists for a given component to back check and document to a "master" prefunctional checklist. That is, each component will normally require the participation of more than one discipline to complete the installation. Each of these sub-contractors will have submitted a prefunctional checklist with the respective sections relating to their scope of work completed. The Builder is to collect these documents and, as part of the back check activity, complete a prefunctional checklist representing the completion of all activities associated with a component without distinguishing the boundaries of any discipline.

Deficiencies and Non-Conformance

The Builder clearly lists any items from initial start-up and prefunctional procedures that were not completed successfully. This information is provided to the Cx team within two days of completion and at the time of submission of the prefunctional checklist. Sub-contractors work to correct deficiencies or uncompleted items, involving the College, A/E, or others as necessary. The Cx team recommends approval of startup and initial checkout of each system to Spelman and Brookwood on the Prefunctional Checklist cover "Request for Functional Test."

Functional Performance Testing Procedures

Overview and Process

Prior to functionally testing any given system, a Prefunctional Checklist will be submitted to Brookwood and the Cx team with necessary signatures and supporting documentation confirming system is ready for FPT. The Cx Team schedules functional tests through Brookwood, the Builder, and the respective Subs. The Cx Team oversees, witnesses, and documents functional testing of all equipment and systems according to the Cx Specifications and Cx Plan. Sub-contractors demonstrate comprehensive functionality of systems to the Cx team.

The control system is tested before it is used to verify performance of other components or systems. The air and water balancing is completed and debugged before functional testing of air or water related equipment or systems. Testing proceeds from subsystems to systems and finally to interlocks and connections between systems.

Deficiencies and Retesting

The Cx Team documents the results of each test. Corrections of minor installation or sequence of operation deficiencies are made during tests at the discretion of the Cx Team. All deficiencies are recorded to the punch list. Deficiencies corrected at the time of discovery are documented so that all issues can be tracked and recorded.

Deficiencies/non-conformance issues not corrected during testing are recorded to the master action list for remedial action. Upon completion, a request is made to the Cx Team for a retest.

Facility Staff Participation

Spelman's facilities operating staff will be notified so they may attend and participate in the testing process.

O&M Manuals and Warranties

Standard O&M Manuals

The Builder submits O&M manuals and submittals in accordance with contract documents to A/E prior to execution of work. A/E approved copies are forwarded to Cx Team for review. The A/E and the Cx Team will review final O&M information prior to turnover to the college.

Cx Record

The Cx Team will compile, organize and index Cx data into labeled, indexed and tabbed three-ring binders and deliver to Spelman and Brookwood. Correspondence, meeting minutes, progress reports, miscellaneous notes, etc. kept during construction will not be included in this record.

Training and Orientation of Spelman Personnel

The Builder will submit a training plan and agenda to Spelman and the Cx team. The Cx team will review the plan for determination that the training agenda addresses the installed

system, is comprehensive and will be administered by qualified individuals. The Cx team returns the reviewed training plan with comments.

The Builder incorporates any comments and schedules training with the Builder and Cx team.

Design and O&M Orientation Session

The intent of A/E orientation session is to have the design, construction and Cx leaders facilitate an informational session for Spelman users and maintainers highlighting the features and functionality of the new Residence Hall.

A/E

The A/E will provide a general overview of the facility, its use, special features, tenant and public considerations, etc. The intended audience may be users or facility maintenance staff and will address design features of the building as well as incorporate instruction for special equipment and devices used in the construction of the building. Solicitation for the services of vendors may occur for this activity.

The mechanical, electrical, plumbing, and fire protection engineers will provide an overview of major systems and equipment in the facility. Included for each system or area of the facility:

- Overview of the facility, its features and capabilities
- The design intent and theory of operation for each significant system
- An overview of system interaction
- Issues regarding future expansion and remodeling, etc.

Narratives of the overview will be incorporated into the facility management guide. More details regarding this overview will be developed as training become imminent.

Warranty Period

During the warranty period, seasonal testing and other deferred testing required are completed according to the Specifications. The CxP coordinates this activity with the Builder. Tests are executed and deficiencies corrected by the appropriate Sub contractors, witnessed by facilities staff and the CxP. Any final adjustments to O&M manuals and as-built documents due to testing are made. The CxP will return to the site at 10 months 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. The CxP will interview facility staff and identify problems or concerns they have with operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Lastly the CxP will identify areas that may come under warranty or under the original construction contract and assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.

Final Summary Report

A final summary report by the CxP will be provided to Spelman College and Brookwood. The report will be submitted following the completion of FPT, training, submission of approved O&M manuals and reconciliation of the project action and punchlist.

The report will include an executive summary, an overview of Cx and testing results and the general disposition of the team regarding the delivered product.

Appendices will contain acquired deficiency lists, findings, unresolved issues, communications, etc. Prefunctional checklists, functional tests, monitoring data, and analysis will be provided in a separate labeled binder.

Systemic Overview and Plan for FPT

General

Tests indicated herein are general functional testing requirements that apply to typical equipment, systems, sub-systems, etc. CxP shall prepare itemized testing plans and procedures that will Specify individual tests and procedures that meet the general requirements of this plan and serve to document and record the testing procedures and the results of the tests.

Coordination between Testing Parties

Factory Start Ups: For many systems and equipment, factory start ups are specified. These generally are Start Up related activities that will be reviewed and checked during FPT. All costs associated with the factory start ups are included with the bid unless otherwise noted. In general, the Builder shall make notification of when these factory start-ups are occurring and coordinate these with witnessing parties. CxT members may witness many of these start ups at their discretion. Aspects of FPT accomplished during the factory start up may be accomplished and approved by the CxP if they judge they meet the intent of the FPT.

Independent Testing Agencies: For systems where independent testing agencies are specified, the cost of this testing is included with the bid unless otherwise noted. Much of the testing performed by these independent agencies will cover aspects required in the start ups and functional performance tests. Builder and testing agencies shall coordinate with the CxP so that they can witness the testing and approve the applicable aspects of the FPTs. CxP may in some cases independently spot check work of the testing agencies if the tests were not witnessed. However it is not the intent for the CxT to reaccomplish testing that is specified in the construction specifications. For instance much of the testing requirements for the electrical systems will be performed by the independent electrical testing agency provided with under the bid. CxP will witness the indicated sample of the testing and record the results in the record of FPT.

Prerequisites

All equipment, components and devices applicable to the test must be started and this start up must be documented. This includes completion of the checklists, pressure testing of equipment, duct, pipe, etc., flushing/cleaning of applicable systems, completed labeling and identification, completed insulation of applicable systems, completed TAB, etc..

Unless specifically agreed to by Spelman, Brookwood and the CxP, all support systems shall be complete prior to FPT. An air handler, for instance, will require that:

- The electrical system serving it is completed and tested
- The air and hydronic systems serving it have been balanced
- The control systems have been started and calibrated.

The CxP shall determine the optimal sequence of testing

Instrumentation

- Standard instrumentation used across generic systems shall be provided to the CxP for spot checking balancing, controls and electrical power quality.
- Proprietary instrumentation required to verify performance of specialty equipment shall be provided by Builder and made available to CxP.
- All equipment used for testing and calibration shall be NIST/NBS traceable and calibrated within the preceding 6 month period. Certificates of calibration shall be submitted.

Common Elements for All Systems

- Have the required submitted documentation convenient to testing area.
- Validate that all required documentation has been submitted and is per the contract requirements.
- The Builder shall provide the start up documentation at the time of testing. Review the start up tests and checklist documentation. The checklists and start up tests/measurements shall be spot checked at the beginning of FPT.
- Builder shall demonstrate that access is sufficient to perform required maintenance.
- All dynamic systems powered by electricity shall be tested to simulate a power outage to verify proper sequencing.
- Capacities and adjusted and balanced conditions as applicable will generally be checked.
- Sequencing Verification: All modes of operation and actions shall be verified for equipment/system samples.
- Configurations shall be compared against the contract documents.
- Verify modes (heating and cooling for instance) are coordinated.
- All adjusted, balanced, controlled systems shall be assessed to determine the optimal setting for the system as applicable. The optimal settings should be determined to establish reliable, efficient, safe and stable operation.
- Dynamic Graphics: The graphic for all components, systems, and areas sampled and required to be represented by a graphic shall be checked for adequacy and accuracy. Furthermore, when setpoints are required to be adjustable, verify that they can be adjusted directly from the graphic screen.
- The CxP will spot check readings from the TAB reports. The readings selected by the CxP will include supply air diffuser readings (both minimum and maximum readings for VAV boxes), main and branch supply duct traverse readings, outside/return air flow readings, exhaust air flow readings, water flow readings, water pressure drop readings through coils, heat exchangers, etc All readings not within allowable error per specification shall require re-balancing.

Specific tasks and general overview. The following items may not be representative of all systems designated under the Cx scope of work.

Automatic Temperature Controls

- Participants shall include CxT, MC, and CC.
- Trends on control systems shall have been established as required in the documents. These shall generally be reviewed prior to or during FPT.
- Controls system sampling will typically correspond to the sampling rate of a system or piece of equipment. These sampling rates are indicated above for the respective item.

- Sub-contractor shall operate the equipment and subsystems through all specified modes of control and sequences of operation including full and part load conditions, and emergency conditions.
- Verify that equipment operates in accordance with design intent and approved control diagrams. This shall include checking the operation of dampers, valves, smoke detectors, high and low limit controls.
- Analog Input Sensors: (at a sample of 50% of the inputs on the sampled devices (see above for device samples) with a maximum failure rate of 10%) Spot check analog input sensors (space temperature sensors, outside, return, and mixed air temperature sensors, discharge air temperature sensors, chilled water and hot water temperature sensors, and humidity sensors, air and water differential pressure sensors, airflow monitoring stations, etc.) for acceptable accuracy (which is generally as specified for the device).
- Valves, Dampers and Actuators: (at a sample of 50% of the inputs on the sampled devices (see above for device samples) with a maximum failure rate of 10%) Ensure that valves and dampers and their actuators close off or seal against the maximum pressure differential. Ensure that the actuators stroke throughout the correct range.
- Establish trends of control system points for a minimum of a two week period prior to and throughout the Acceptance period. Trends shall be analyzed to identify any control problems, lack of capacity, control loops fighting or unstable, etc.
- Spot (at a sample of 50% of the inputs on the sampled devices (see above for device samples) with a maximum failure rate of 10%) check the operation of all automatic switches (pressure switches, current switches, flow switches, etc.) to ensure that they are adjusted to proper make and break settings.
- Verify the stand alone functionality of the controllers. Generally disconnect LAN communication wiring and ensure that the controller functions properly and that the loss of communication is acknowledged by the interface. Restore communications and ensure an orderly restoration to normal control.
- Verify that the BAS interface, BAS software, graphics and functions are in accordance with design intent and approved control diagrams.
- Check dial in communications where applicable to ensure functionality.

HVAC System Pumps Functional Performance Test

- Participants include CxT, MC, TAB, and CC
- CxP shall review start-up check-list, and TAB report.
- Builder shall demonstrate that strainers are clean.
- Pumps shall be manually started individually. Pressure differential, KW (or slip on the motor), and flow shall be checked at shut-off, wide open, and balanced (or controlled) condition. Generally the reading from the instrumentation provided with the pump (thermometers and pressure gages and flow meters as applicable) will be acceptable if used to validate an action as opposed to checking balancing.
- For pumps designed with automatic starting of back up pump on primary pump failure, enable automatic controls, start primary pump, throw disconnect switch of primary pump, and validate that standby is energized. Perform this test on both pumps.
- For variable speed pumps, manipulate control valves to change flow conditions and observe control response. Ensure stable control response to step change in flow conditions. Check for the applicable acceleration and deceleration of the pumps. Manually ramp pump speed from min. to max. to ensure stable operation of pumps and record/defeat any critical frequencies. Record representative part load output

from the drive (using VFD read out). Check calibration of control input. Check drive bypass operation if applicable.

- Simulate power outage and ensure orderly and automatic restart.

Building Chilled Water Loop Connection FPT

- Participants shall include CxT, MC, TAB, and CC
- Open building control valve, measure and record flow to the building and pressure differential.
- Command the building valve to close and verify adequate shut off.
- Enable automatic control of the building loop and trend performance. Make at least one step change in the loop setpoint during the trend period.
- Refer to HVAC Systems Pumps for pump testing. Additionally, with a fixed setpoint on the building valve control loop, establish a trend on the pump control loop. Observe normal control function. Introduce one setpoint step change and observe response.
- Observe system performance. Trend all values and print trend for documentation.
- Verify all energy meters have been connected, all calculations are running, and totalization routines are enabled.

Hot Water to Hot Water Converter Functional Performance Test

- Participants shall include CxT, MC, TAB, and CC.
- CxP shall review start-up checklist and TAB report.
- Builder shall start and warm-up the converter.
- Record Hot water system pressurization and ensure that the air has been removed and the system is under positive pressure at all points in the system.
- Verify proper steam pressure upstream of valve and proper water flow through converter.
- Verify that control valve(s) modulates/stages to maintain water temperature. Verify proper sequencing of valves where applicable. Observe control response to varying loads and ensure stable response. Loads should be varied by Builder by starting and stopping air handling units or other suitable means.
- Set valves and flow for full heating and verify maximum heating capacity.
- Verify that condensate is flowing freely and that traps are operating properly.
- Verify proper operation of makeup water system, including chemical treatment, etc., where applicable.

Fan Coil Unit Functional Performance Test

- Participants shall include CxT, MC, TAB, and CC.
- CxP shall review start-up check-lists and TAB reports.
- Verify automatic start/stop of fan and open/close of outdoor air damper.
- Start heating and cooling system, manipulate control device to obtain maximum cooling and heating. Measure temperatures and pressures to determine capacity.
- Weather permitting cause all applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
- Check calibration of control devices and for stable control response.
- Check for free and adequate flow of cooling coil condensate.
- Simulate power outage and ensure automatic and orderly restart.

Air Handling Unit Functional Performance Test

- Participants shall include CxT, MC, TAB, and CC.
- CxP will select a representative amount or all air handling units for testing.
- CxP shall review start-up check-lists and TAB reports.
- Verify automatic start/stop of fan and open/close of outdoor air damper.
- Start heating and cooling system, manipulate control device to obtain maximum cooling and heating. Weather permitting cause all applicable modes of operation using false loading where practical. This includes loading of filters and coils for airflow check. Check proper sequence for switching modes and proper operation within a mode.
- Check calibration of control devices and for stable control response and component performance including chilled water coils, hot water coils, humidifiers, etc. Ensure proper coordination of control loops and that no fighting or energy wastes result.
- Check for free and adequate flow of cooling coil condensate.
- For variable speed fans, manipulate air terminal units to change flow conditions and observe control response. Ensure stable control response to step change in flow conditions. Manually ramp fan speed from min. to max. to ensure stable operation of fans. Record representative part load output from the drive. Check calibration of control input. Check drive bypass operation if applicable.
- Test all interfaces with the fire alarm system and all smoke control sequences.
- Verify interlocks with exhaust fans where applicable.
- Test proof alarming where applicable.
- Test operation of applicable safeties including freeze stats, high and low static devices, smoke detection, etc. Check AH component status in each event.
- Check system status and operation in the Off, Unoccupied, and Occupied Mode of operation. Validate proper start up and shut down sequences.
- Simulate power outage and ensure automatic and orderly restart.
- Verify unit will run in all manual override conditions, including hand and bypass conditions.

VAV Air Terminal Functional Performance Test

- Participants shall include CxT, MC, TAB, and CC.
- CxP shall review start-up check-lists and TAB reports.
- Check the calibration of zone temperature sensors.
- Set boxes for both minimum and maximum flow (typically by setting the space temperature setpoint up and down) and check the calibration of the flow settings.
- Verify a dead-band exists between the reheat and damper modulation actions.
- Check the stability of the zone temperature control loop for the damper and any associated heating devices by changing the space setpoints and observing the response.
- Cause all applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
- Determine the optimal settings for the control parameters.
- Simulate and test the unoccupied and emergency mode response of the box where applicable.
- Check the capacity of the heating device where applicable.

Emergency Generators and Automatic Transfer Switch

- Participants shall include CxT, EC
- Spot check start ups and factory tests. Record system settings and parameters.
- Open normal breakers to simulate various levels of power outages including all utility feeds, single feed, transformers, and distribution panels.
- With each outage test configuration, observe generators start and take load. Record volts, amps, frequency, power factor phase angle for all phases for all generators. Monitor engine temperatures. Monitor battery charge.
- With each partial outage, record timing parameters of tie breaker closure.
- With each outage test configuration, fail generators successively (by simulating different support system component failures including fuel delivery as well as engine safety trips including high temp, high oil pressure, low oil pressure, over-speed) and observe priority demand control dump load to the highest priority. Restore generators and see the demand control restore all priority blocks. Ensure generator support systems remain to highest priority.
- Observe fuel delivery capacity at peak loads. Fail sample delivery systems de-energizing the feed pumps. Verify low level alarms on the day tanks.
- With systems operating on emergency power, spot check power parameters of all systems on emergency power. Emergency testing of individual systems are covered under those systems. In conjunction with the generator testing, test the UPS systems. Refer to that item below for more detail.
- Measure noise levels.
- Restore normal breakers and observe systems retransfer to normal. Record timing of tie breakers opening. Observe generator cool down and shut down sequence and record parameters.
- Observe the transfer switch during power outage simulation (both during outage and retransfer to normal). Validate timing and sequences.
- Test the load test function and the maintenance bypass function.

Lighting System

- Participants shall include CxT, EC
- Verify lighting controls – all switches, occupancy sensors, etc.
- Test the cables using Sub-contractor supplied instrument and technician.
- Spot check lighting levels (footcandle) using illuminometer.
- Verify alignment of directional fixtures.

Grounding System

- Participants shall include CxT, EC.
- General—Check compliance of overall grounding and bonding system with NEC Article 250 – Grounding and Bonding.
- Verify all available building grounding electrodes are bonded together per NEC 250.50.
- Spot check size and connectors of transformer secondary bonding jumpers.
- Spot check outlet box and equipment case bonding connections.
- Ohmmeter building grounding system.

Fire Alarm System

- Participants shall include CxT, EC, CC.
- General—Check compliance of overall fire system with NFPA 72.

- Spot check all fire loops for grounds, shorts, and open circuits.
- Spot check the supervision of all devices. Test will involve the removal of devices and in some cases the disconnection and shorting of fire alarm circuits.
- Verify all sequences, including but not limited to equipment interlocks, output messages, remote monitoring systems, etc.

Building Envelope

- Participants shall include CxT, RC, CWC.
- Review quality control activities to determine if specified procedures and methods are being utilized.
- Witness functional performance testing performed by builder of roofing and envelope systems.
- Testing will include a roof moisture survey, water testing of curtain wall systems, and other quality assurance testing required by the specifications.