

MIT

Design Standards

Commissioning

T07 Thematic Folder

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Department
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1. COMMISSIONING

1.1 Project Commissioning Manual

Refer to the Project Commissioning Manual following this document.

END OF DOCUMENT



Massachusetts Institute of Technology

Department of Facilities

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PROJECT COMMISSIONING STANDARD (PCS)

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1.0 GENERAL

1.1 RESPONSIBLE PERSONNEL

- A. Commissioning Authority: An independent commissioning authority/agent will be retained by the Owner to act as the Commissioning Authority (CxP) for the Project. The CxP directs and approves the commissioning work.
- B. Responsibility of Disciplines: The parties listed below are part of the commissioning team and are required to participate in the commissioning process. The responsibilities relative to commissioning for each of these parties are defined in this section in addition to those required elsewhere in the contract documents.
1. Architect
 2. Engineer
 3. Owner
 4. Construction Manager
 5. General Contractor
 6. Mechanical Contractor
 7. Plumbing Contractor
 8. Electrical Contractor
 9. Controls Contractor
 10. Fire Alarm Contractor
 11. Fire Protection Contractor
 12. Testing, Adjusting and Balancing Contractor
 13. All Subcontractors, vendors and suppliers that are associated with the above disciplines

1.2 DESCRIPTION

- A. Commissioning: Commissioning is a systematic process of verifying that all building systems perform interactively according to the design intent and the Owner's operational needs. This is achieved during construction, testing and the warranty period with actual verification of performance. The commissioning process shall encompass and coordinate the functions of system documentation, equipment installation, equipment startup, control system calibration, testing and balancing, performance testing, integrated systems testing and training.

**IF PROJECT IS FOLLOWING LEED RATING PROGRAM, REVISE PARAGRAPHS 1.2.B & 1.2.C
BELOW AS APPROPRIATE TO MEET PROJECT REQUIREMENTS**

- B. This project has a goal of achieving a gold rating using **LEED Version 4.1** and has implemented the commissioning program to meet the specific requirements of the EA Fundamental Commissioning and Verification Prerequisite and the EA Enhanced Commissioning Credit.
1. To achieve the LEED EA Fundamental Commissioning and Verification Prerequisite the commissioning process is required to achieve the following specific objectives:
 - Review the OPR, BOD, and project design.
 - Develop and implement a Commissioning plan.
 - Confirm incorporation of commissioning requirements into the construction documents.

- Develop construction checklists.
- Develop a system test procedure.
- Verify system test execution.
- Maintain an issues and benefits log throughout the commissioning process.
- Prepare a final commissioning process report.
- Document all findings and recommendations and report directly to the Owner throughout the process.
- Prepare and maintain a current facilities requirements and operations and maintenance plan that contains information necessary to operate the building efficiently. The plan must include the following:
 - a sequence of operations for the building;
 - the building occupancy schedule;
 - equipment run-time schedules;
 - set points for all HVAC equipment;
 - set lighting levels throughout the building;
 - minimum outside air requirements;
 - any changes in schedules or set points for different seasons, days of the week, and times of day;
 - a systems narrative describing the mechanical and electrical systems and equipment;
 - a preventive maintenance plan for building equipment described in the systems narrative; and
 - a commissioning program that includes periodic commissioning requirements, ongoing commissioning tasks,
 - and continuous tasks for critical facilities.

2. To achieve the LEED Enhanced Commissioning Credit, the commissioning process is required to complete the following commissioning process (CxP) activities:

OPTION 1 – ENHANCED SYSTEMS COMMISSIONING

For mechanical, electrical, plumbing, and renewable energy systems and assemblies in accordance with ASHRAE Guideline 0–2013 and ASHRAE Guideline 1.1–2007 for HVAC&R systems, as they relate to energy, water, indoor environmental quality, and durability:

- Review Contractor submittals.
- Verify inclusion of systems manual requirements in construction documents.
- Verify inclusion of operator and occupant training requirements in construction documents.
- Verify systems manual updates and delivery.
- Verify operator and occupant training delivery and effectiveness.
- Verify seasonal testing.
- Review building operations 10 months after substantial completion.
- Develop an on-going commissioning plan.
- Include all enhanced commissioning tasks in the OPR and BOD.

- Develop monitoring-based procedures and identify points to be measured and evaluated to assess performance of energy- and water-consuming systems.
 - Include the procedures and measurement points in the commissioning plan. Address the following:
 - Roles and responsibilities;
 - Measurement requirements (meters, points, metering systems, data access);
 - The points to be tracked, with frequency and duration for trend monitoring;
 - The limits of acceptable values for tracked points and metered values (where appropriate, predictive algorithms may be used to compare ideal values with actual values);
 - The elements used to evaluate performance, including conflict between systems, out-of-sequence operation of systems components, and energy and water usage profiles;
 - An action plan for identifying and correcting operational errors and deficiencies;
 - Training to prevent errors;
 - Planning for repairs needed to maintain performance; and
 - The frequency of analyses in the first year of occupancy (at least quarterly).
 - Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design

AND/OR

OPTION 2 – ENVELOPE COMMISSIONING

For the building's thermal envelope in accordance with ASHRAE Guideline 0–2013 and ASTM E2947-16, Standard Guide for Building Enclosure Commissioning, as they relate to energy, air and water tightness, indoor environmental quality, and durability:

- Review Contractor submittals.
- Verify inclusion of systems manual requirements in construction documents.
- For specialty enclosure systems with controls and automation:
 - Verify inclusion of operator and occupant training requirements in construction documents.
 - Verify systems manual updates and delivery.
 - Verify operator and occupant training delivery and effectiveness.
 - Verify seasonal testing.
 - Review building operations 10 months after substantial completion.
- Develop an on-going enclosure commissioning plan for maintenance, renewal and revitalization cycles.

NOTE: For projects with peak cooling loads 2,000,000 Btu/h (600 kW) or more, or a total computer room peak cooling load 600,000 Btu/h (175 kW) or more, the CxP must conduct at least three verification reviews of the basis of design:

- One verification review of design documents before the start of design development;
- One verification review of design documents before mid-construction documents; and
- One final verification review of 100% complete design documents, verifying achievement of the Owner's project requirements and adjudication of previous review comments.

DATA CENTERS ONLY

Projects that select Option 1 must complete the following commissioning process. For small projects with peak cooling loads less than 2,000,000 Btu/h (600 kW), or a total computer room peak cooling load less than 600,000 Btu/h (175 kW), the CxP must perform the following activities:

- Conduct at least one commissioning verification review of the Owner's project requirements, basis of design, and design documents before mid-construction documents development;
- Back-check the review comments in all subsequent design submissions; and
- Conduct an additional full verification review at 95% completion of the design documents and basis of design.

- C. In addition to the requirements outlined by the LEED program, commissioning during the construction phase shall as a minimum, achieve the following specific objectives in concert with the contract documents:
1. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations, to industry accepted minimum standards, per the contract documents and that they receive adequate operational checkout and testing by installing Contractors and suppliers.
 2. Verify and document proper performance of each piece of equipment as well as all integrated operating systems.
 3. Verify that the As-Built Drawings have been properly completed.
 4. Verify that the equipment and systems comply with the contract documents. Identify non-complying items.
 5. Issue a "Recommendation of Acceptance" to the Owner stating that the equipment and systems have successfully passed functional and integrated performance testing. Describe the equipment and/or systems that have failed and not passed and make a recommendation for acceptance or rejection of each by the Owner.
 6. Verify that O&M documentation delivered to the Owner is complete.
 7. Verify that Owner's operations staffs are properly trained.
- D. The commissioning process does not negate, take away from or reduce the responsibility of the system designers or installing Contractors to provide a finished and fully functioning product as required by their contracts.
- E. This project will have selected building systems commissioned. The Commissioning Authority will coordinate the commissioning process. All correspondence will flow through the Construction Manager with copies to the Owner's Project Manager.

- F. Abbreviations: The following are common abbreviations used in the Specifications and in the commissioning process.

A/E-	Architect and Design Engineers
BOD-	Basis Of Design
CC-	Controls Contractor
CM-	Construction Manager
Cx-	Commissioning
CxP-	Commissioning Professional
EC-	Electrical Contractor
FC-	Façade Contractors (Those responsible for installing the façade systems)
FPC-	Fire Protection Contractor
FPT-	Functional Performance Test
GC-	General Contractor
IST-	Integrated System Test
MC-	Mechanical Contractor
O&M-	Operation and Maintenance Manuals
OPR-	Owner's Project Requirements
PC-	Plumbing Contractor
PFC-	Pre-functional Checklist
PM-	Project Manager (of the Owner)
RC-	Roofing Contractor
SOO-	Sequence Of Operations
Subs-	Subcontractors to General
TAB-	Test and Balance Contractor

1.3 DEFINITIONS

- A. Basis of Design - The basis of design is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The basis of design describes the systems, components, conditions and methods chosen to meet the intent.
- B. Control system - The building energy management control system.
- C. Cx Process – Refers to the Commissioning Process.
- D. Data logging - Monitoring flows, currents, status, pressures, etc. of equipment using stand-alone data loggers separate from the control system.
- E. Deferred Functional Tests - FPTs 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.
- F. 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).
- G. 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.
- H. Design Narrative or Design Documentation - Sections of either the Design Intent or Basis of Design.

- I. Factory Testing - Testing of equipment on-site or at the factory-by-factory personnel with an Owner's representative present.
- J. Functional Performance Test (FPT) - 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. Systems are tested under various modes, such as during cooling or heating loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, emergency power, 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. The commissioning authority develops the functional test procedures in a sequential written form, coordinates, observes and documents the actual testing, which is performed by the installing Contractor or vendor. FPTs are performed after pre-functional checklists and startups are complete.
- K. Indirect Indicators - Indicators of a response or condition, such as a reading from a control system screen reporting a damper to be 100% closed.
- L. Integrated Systems Test (IST) - Integrated testing verifies the performance of systems operating in conjunction with one another under various modes of operation conform with design documents. Final testing of systems interactively, using failure analysis and "what if" scenarios to determine the ability of systems to provide continuous and safe operation. ISTs follow successful completion of FPTs.
- M. 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").
- N. Monitoring - The recording of parameters (flow, current, status, pressure, etc.) of equipment operation using data loggers or the trending capabilities of control systems.
- O. Non-Compliance - See Deficiency.
- P. Non-Conformance - See Deficiency.
- Q. 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."
- R. Owner-Contracted Tests - Tests paid for by the Owner outside the Contractor's contract and for which the CxP does not observe. These tests will not be repeated during functional tests if properly documented.
- S. 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.
- T. Pre-Functional Checklist (PFC) - A list of items to inspect and component tests to conduct to verify proper installation of equipment, by the Contractor. 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.). Some pre-functional checklist items may entail simple testing of the function of a component, a piece of equipment or system. The word pre-functional refers to before functional testing. Pre-functional checklists augment and are combined with the manufacturer's start-up checklist. The commissioning authority only requires

that the procedures be documented in writing, and does not witness the pre-functional check listing.

- U. Sampling - Functionally testing only a fraction of the total number of identical or near identical pieces of equipment.
- V. Seasonal Performance Tests - FPT that are deferred until the system(s) will experience conditions closer to their design conditions.
- W. 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).
- X. 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.
- Y. Startup - The initial starting or activating of equipment, including executing pre-functional checklists.
- Z. Systems Manual - The Systems Manual is intended to be useful in the day-to-day operations of a facility. The Systems Manual expands the scope of the traditional operating and maintenance documentation to include the additional information gathered during the Commissioning Process and to provide a systems-based organization of information.
- AA. Testing Phase - Phase of construction after startup and initial checkout when functional performance tests, O&M documentation review and training occur.
- BB. Test Procedures - The step-by-step process, which must be executed to fulfill the test requirements. The CxP develops the test procedures.
- CC. Test Requirements - Requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures.
- DD. Trending - Monitoring using the building control system.

1.4 COORDINATION

- A. Management: The CM will coordinate the efforts of the Contractors and vendors so that the commissioning process is coordinated and completed in advance of substantial completion except for deferred tests.
- B. Scheduling: The Cx process milestones shall be established and documented in the Cx Plan. These milestones shall serve as the basis for the detailed commissioning activities incorporated into the master project schedule by the CM. The schedule shall be updated throughout the project with input from the CxP, Owner and Contractors during the commissioning meetings.

1.5 COMMISSIONING PROCESS

- A. Commissioning Process: The following is a brief overview of the typical commissioning tasks during construction and the general order in which they shall occur.

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1. Commissioning during construction shall begin with a scoping meeting conducted by the CxP wherein the testing and balancing and commissioning processes are reviewed with the commissioning team members.
 2. Additional regularly scheduled meetings by the CM are required throughout construction, to plan, scope, coordinate, and schedule future activities and resolve problems.
 3. Approved equipment documentation shall be submitted to the Engineer during normal submittals, including detailed start-up procedures. The CM shall copy the CxP on all equipment that is to be tested. The CxP will review and comment on applicable items as appropriate.
 4. The CxP may request additional information for manufacturers test procedures by submitting all requests through the CM who will forward to the responsible Contractor.
 5. The Subcontractors shall develop startup plans and startup documentation formats and provide to the CM who will forward to the CxP.
 6. The Subcontractors shall execute and document the pre-functional checklists and perform prior to startup and initial checkout. The CxP may witness start-up of selected equipment at his option.
 7. The CxP shall develop specific equipment and system functional performance test and integrated system test procedures. The Subcontractors shall review the procedures and plans.
 8. The procedures shall be executed by the Subcontractors, under the observation of, and documented by the CxP.
 9. Items of non-compliance in material, installation or setup shall be corrected at the Sub's expense and the system retested.
 10. The CxP shall review the O&M documentation for completeness as prepared by the Subcontractors and vendors.
 11. Training of the Owner's personnel should be provided by the designers, Contractors, vendors and suppliers for all systems and equipment operation and maintenance in a manner approved by the CxP and coordinated through the CM and CxP.
 12. Commissioning shall be completed before and is a prerequisite for Substantial Completion.
 13. Seasonal testing shall be conducted in the opposite season from functional tests.
- B. Building Envelope Review Process: The following narrative provides a brief overview of the typical building envelope review tasks during construction and the general order in which they occur.
1. Building envelope review during construction begins at the Cx scope meeting conducted by the CxP where the building envelope review process is reviewed with the team members.

2. Additional meetings will be required throughout construction, scheduled by the CxP with necessary parties attending, to plan, scope, coordinate, schedule future activities and resolve problems.
3. Building envelope documentation is submitted to the CxP during the normal submittals process, including detailed installation procedures.
4. An additional “Pre-installation” meeting will be convened a minimum of two weeks prior to commencing envelope work reviewed in this section. Attendees shall include representatives of each building envelope component, the exterior wall installers, and project superintendent. Agenda shall include the following:
 - a. Review of approved submittals
 - b. Review of mock-ups
 - c. Coordination with sequence of installation with adjacent materials
 - d. Schedule for building envelope components
 - e. Procedures for quality assurance
5. The CxP works with the Subs in developing the mock-up program for building envelope including which configurations should have mock-ups, when they should be completed, notification requirements of completion, tests to be performed and who shall witness and evaluate each mock-up.
6. As construction progresses, the CxP will periodically perform site walk-downs of the building envelope components and installation and document any issues or deficiencies identified.
7. The Subs, under their own direction, will complete mock-ups in accordance with the building envelope mock-up program and notify the building envelope team that the mock-ups are ready for evaluation. The CxP evaluates the mock-ups and documents observations and test results as applicable.
8. The mock-up test procedures are created and executed by the Subs and witnessed by the CxP. Items of non-compliance in material, configuration or installation are corrected at the Sub’s expense and the system retested.
9. Between the installation of each building envelope component, the CxP will perform a periodic inspection and final punch list inspection of each building envelope component and document items of non-compliance in material, configuration or installation.

1.6 RELATED WORK

A. All of the following divisions apply to the Work of this section.

1. 010000 LEED Requirements
2. 010000 Closeout Procedures
3. 010000 Operation and Maintenance Requirements
4. 080000 Building Envelope
5. 210000 Fire Protection
6. 220000 Plumbing Systems
7. 230000 Heating, Ventilating, and Air Conditioning
8. 250000 Integrated Automation
9. 260000 Electrical
10. 270000 Communications

1.7 COMMISSIONING COMPLETION

A. Prerequisites to functional completion

1. All TAB work and commissioning activities must be complete prior to Functional Completion, unless approved in writing by the Owner. This includes for all systems, but is not limited to:
 - a. Completed and signed start-up and PFCs
 - b. Requested trend log data
 - c. Submission of final approved TAB report
 - d. Completion of all functional and integrated testing
 - e. Submission of the approved O&M manuals
 - f. Required training of Owner personnel completed and approved
 - g. Identified deficiencies have been corrected or are Owner approved.
2. Exceptions to the Functional Completion are any required seasonal or approved deferred testing.

B. Commissioning activities are non-compensable and cannot be a cause for delay claims.

1.8 SYSTEMS TO BE COMMISSIONED

- A. The following systems as a minimum shall be commissioned in this project. The matrix below provides a listing of the systems along with an indication of the responsibility for each. Preliminary testing requirements are part of this section. Each member of the commissioning team shall review all test procedures in this section to determine if his/her presence is required for each test. Certain tests of mechanical equipment may require the support of electrical personnel and vice versa.

NOTE: Testing listed below does not reduce or eliminate other testing requirements called for in any other section of this specification document.

THE MATRIX BELOW IDENTIFIES THE MINIMUM REQUIREMENTS FOR MIT PROJECTS. HOWEVER, THE MATRIX SHALL BE ADJUSTED FOR EACH PROJECT BASED ON THE APPLICABLE SYSTEMS INVOLVED, SYSTEM COMPLEXITY AND SYSTEM CRITICALITY.

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Systems	PFC Req'd	Start-up plan	FPT Sample Rate	FPT/IST Testing				
				Create	Execute	Support	Witness	Document
Heating, Ventilating & Air Conditioning								
1. Air Systems								
a. Miscellaneous Supply, Transfer and Return Air Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
b. Lab Supply Air Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
c. Vivarium Supply Air Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
d. Cleanroom Supply Air Systems (MAHUs)	✓		100%	CxP	CC	MC/EC	CxP	CxP
e. Cleanroom Recirculation Air Systems (RAHUs)	✓		100%	CxP	CC	MC/EC	CxP	CxP
f. Clean Stair and Elevator Hoist Way Pressurization Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
g. Heat Recovery Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
2. Exhaust Systems								
a. Miscellaneous Exhaust Air	✓		100%	CxP	CC	MC/EC	CxP	CxP
b. Fume and Special Exhaust Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
c. Kitchen Hood Exhaust Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
3. Life Safety Exhaust Air Systems								
a. Freight Elevator Pressurization System	✓		100%	CxP	CC	MC/EC	CxP	CxP
b. Elevator Pressurization System	✓		100%	CxP	CC	MC/EC	CxP	CxP
4. Duct and Terminal Distribution Systems								
a. Variable Air and Constant Air Volume Systems	✓		20%	CxP	CC	MC/EC	CxP	CxP
b. Phoenix Air Valve Systems	✓		100%	CxP	CC	MC/EC	CxP	CxP
c. Test, Adjust & Balance			10%	TAB	TAB	CC	CxP (Audit)	TAB
5. Hydronic Systems								
a. Chilled Water System	✓		100%	CxP	CC	MC/EC	CxP	CxP
b. Vivarium Chilled Water System	✓		100%	CxP	CC	MC/EC	CxP	CxP
c. Process Chilled Water System	✓		100%	CxP	CC	MC/EC	CxP	CxP
d. Condenser Water System	✓		100%	CxP	CC	MC/EC	CxP	CxP
e. Heating Hot Water System	✓		100%	CxP	CC	MC/EC	CxP	CxP
f. Terminal equipment (Unit Heaters, Fan Coil Units, etc.)	✓		20%	CxP	CC	MC/EC	CxP	CxP
g. Glycol Heat Recovery System	✓		100%	CxP	CC	MC/EC	CxP	CxP
6. Steam Systems								
a. Low/ Medium Pressure Plant Steam	✓		100%	CxP	CC	MC/EC	CxP	CxP
b. Medium Pressure Clean Steam	✓		100%	CxP	CC	MC/EC	CxP	CxP
c. Low Pressure Clean Steam Humidification System	✓		100%	CxP	CC	MC/EC	CxP	CxP
7. Control Systems								
a. Automatic Temperature Control			100%	CC	CC		CxP	CC
b. Fume Hood Control			100%	CC	CC		CxP	CC
c. Vivarium Control			100%	CC	CC		CxP	CC
8. Miscellaneous Lab Systems								
a. Fume Hoods (MIT's current modified ASHRAE 110 in place)	✓		100%	CxP	CC	MC/EC	CxP	CxP
b. Bio-Safety Cabinets (test per MIT's current EHS protocols)	✓		100%	CxP	CC	MC/EC	CxP	CxP
Electrical								
1. Distribution								
a. Normal power	✓		20%	EC	EC		CxP (Audit)	EC
b. Emergency Power	✓		100%	EC	EC		CxP (Audit)	EC
c. Medium Voltage	✓		20%	EC	EC		CxP (Audit)	EC

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Systems	PFC Req'd	Start-up plan	FPT Sample Rate	FPT/IST Testing				
				Create	Execute	Support	Witness	Document
d. Standby Power	✓		20%	EC	EC		CxP (Audit)	EC
2. Motor Control Centers	✓		100%	EC	EC		CxP	EC
3. Lighting Control			20%	CxP	EC	CC	CxP	CxP
4. Emergency Lighting			100%	EC	EC	CC	CxP	EC
5. Fire Alarm System (per NFPA Standard 3 & 4)	✓		100%	CxP	EC	CC/MC	CxP	CxP
6. Smoke detection	✓		100%	CxP	EC/CC	MC	CxP	CxP
7. EPO			100%	EC	EC	CC	CxP	EC
Plumbing								
1. Domestic Hot Water Systems	✓		100%	CxP	PC	CC/MC	CxP	CxP
2. Protected/ Non-Domestic Hot Water	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
3. Animal Watering	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
4. Purified (RODI) Water	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
5. RO Recovery System	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
6. Tempered Potable Water for emergency systems (connect to existing)	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
7. Laboratory Gas System	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
8. Carbon Dioxide (connect to existing)	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
9. Medical Oxygen	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
10. Low Pressure Compressed Air (connect to existing)	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
11. Medical Compressed Air	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
12. Lab Vacuum (connect to existing)	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
13. Medical Vacuum	✓		100% (distr. only)	CxP	PC	CC/MC	CxP	CxP
14. pH Neutralization System	✓		100%	CxP	PC	CC/MC	CxP	CxP
15. Lab Waste Ejectors	✓		100%	CxP	PC	CC/MC	CxP	CxP
16. Sewage/Drainage Ejectors	✓		100%	CxP	PC	CC/MC	CxP	CxP
17. Sump Pump	✓		100%	CxP	PC	CC/MC	CxP	CxP
Fire Protection								
1. Combined Sprinkler and Standpipe System			N/A	PC	PC		CxP	PC
2. Dry pipe Sprinkler System			N/A	PC	PC		CxP	PC
3. Pre-Action System			N/A	PC	PC		CxP	PC
4. Kitchen Ansul System	✓		100%	MC	MC	CC/PC	CxP	MC
5. Foam-Water System			N/A	FPC	FPC		CxP	FPC
6. Fire Pump System (including ATS for emergency power)			N/A	FPC	FPC		CxP	FPC
Infrastructure Monitoring and Control								
1. Power Monitoring System			100%	CxP	EC	CC	CxP	CxP
2. Building Management System			100%	CxP	CC		CxP	CxP
3. Toxic Gas Monitoring			100%	CxP	CC		CxP	CxP
4. Utility Metering Systems			100%	CxP	CC		CxP	CxP
Envelope								
1. Roofing System	✓		20%	PC	PC		CxP	PC
2. Window System	✓		20%	PC	PC		CxP	PC
3. Wall System	✓		20%	PC	PC		CxP	PC

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Systems	PFC Req'd	Start-up plan	FPT Sample Rate	FPT/IST Testing				
				Create	Execute	Support	Witness	Document
By Others								
1. Telecommunications								
2. Security								
3. AV System								
4. Sterilizers/ Autoclaves								
5. Cage Washers								
6. Vertical Transportation								

1.9 RESPONSIBILITIES

A. All Parties:

1. **Attend commissioning meetings.**
2. **The Contractors that have been awarded this project will be required to use Facility Grid for the purpose of completion of pre-functional checklists and for responding to commissioning issues. MIT will provide the Contractors with access to Facility Grid and required training for effective use of the software at no cost.**
3. **MIT requires certain MEP/FP components to be inventoried and labeled by the installing Contractor. See the attached Asset Inventory Application guideline, for requirements. As detailed in the guideline, MIT will assign a unique number for each piece of inventoried equipment and will provide a unique metal ID tag etched with the number and the corresponding barcode. These must be applied to each required component; see guidelines for further details. Any equipment which feeds or serves another must be designated in a manner which outlines the sub/superior relationship of the equipment. An example of this, as well as the required parent/child equipment types, is provided in the guideline.**
4. **These do not take the place or diminish other labeling requirements, such as BMS designator or P&ID.**

B. Architect:

1. Construction Phase
 - a. Attend the commissioning scoping meeting and selected commissioning team meetings.
 - b. Provide design narrative documentation requested by the CxP.
 - c. Observe, record, and coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
2. Testing Phase
 - a. Coordinate resolution of design non-conformance and design deficiencies identified during commissioning.

C. Design Engineer:

1. Construction Phase
 - a. Attend the commissioning scoping meeting and selected commissioning team meetings.
 - b. Provide the basis of design narrative and sequences documentation requested by the CxP. The Design Engineers 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.

2. Testing Phase
 - a. Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
 3. Turnover Phase
 - a. Provide training to R&M staff in concert with the Contractor's training.
- D. Construction Manager (CM):
1. Bidding Phase
 - a. CM will make certain that the installing Subcontractors are aware of the TAB and commissioning process and fully embody these requirements into their work effort and work schedule.
 2. Construction Phase
 - a. Facilitate the coordination of the commissioning work by the CxP, and, with the CxP, ensure that commissioning activities are being scheduled into the master construction schedule.
 - b. Attend commissioning scoping meetings and other commissioning team meetings.
 - c. Perform the thorough review of Subcontractor submittals. Provide copies of Subcontractor submittals and/ or data pertaining to all approved equipment that will be commissioned to the CxP.
 - d. Provide a "Certificate of Readiness" document stipulating that all subject equipment, systems and controls are complete and ready for functional performance testing, including building envelope mock-up installations. This certificate shall be signed by the installing Contractors, as well as the GC, and shall be supported by completed pre-functional checklists and start-up reports.
 - e. Observe and witness pre-functional checklists, envelope mock-up installations/ test preparations and startup of selected equipment.
 3. Testing Phase
 - a. Review balancing, commissioning progress and deficiency reports.
 - b. Assist the CxP as necessary in the seasonal or deferred testing and deficiency corrections required by the specifications. This is to include the testing in the "opposite" season.
 4. Turnover Phase
 - a. Provide contact list of Subcontractors and vendors to support post warranty issues. List shall include: name, title, telephone number, email address, and emergency contact information for after-hours service.

- b. Provide a warranty list of installed equipment. The list shall include: equipment type, vendor's name, contact information and email address, and warranty start and duration of individual components.
- E. Owner's Project Manager (PM):
- 1. Construction Phase
 - a. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training.
 - b. Provide final approval for the completion of the balancing and commissioning work.
 - 2. Testing Phase
 - a. Verify that any seasonal or deferred testing and any deficiency issues are addressed.
- F. **All Installing Subcontractors** that have commissioning responsibilities:

The commissioning responsibilities applicable to each of the Subcontractors are as follows (all references apply to commissioned equipment only):

- 1. Construction Phases
 - a. In each purchase order or subcontract written, include requirements for submittal data, commissioning documentation, O&M data, as-builts and training.
 - b. Each Subcontractor is to adhere to the Project Schedule prepared at the time of the GMP/bid as it relates to their trade. Within 30 workdays of commencing work on this project, each Subcontractor is to verify in writing that the schedule complete with the commissioning activities is achievable. If adjustment in the schedules is necessary, they will not be made at the "expense" of the commissioning sequence.
 - c. Attend commissioning scoping meetings and other meetings necessary to facilitate the Cx process.
 - d. Provide additional requested documentation, prior to normal O&M manual submittals, to the CM who will forward to the CxP for development of FPTs.
 - 1) As a minimum, this shall include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any Owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation, start-up and checkout materials that are shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the CxP.

- e. Provide a copy of the O&M manuals of commissioned equipment, through normal channels, to the CxP for review and approval.
- f. Contractors shall assist (with confirmation from 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.
- g. Provide assistance to the CxP in preparing the specific mock-up, envelope FPT procedures. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
- h. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the pre-functional checklists from the CxP for all commissioned equipment. Submit to CxP for review and approval prior to startup.
- i. Execute and document the pre-functional checklists.
- j. Assist the CxP in the development of the Building Envelope Mock-up and Test plan.
- k. Provide skilled technicians, tools, instrumentation, equipment, and materials necessary to execute starting of equipment. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving.
- l. Include CxP in scheduling Contractor testing and start-ups to allow for witnessing as required by the CxP.
- m. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CxP.
- n. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.
- o. Provide completed pre-functional checklists and start-up reports, signed by the responsible parties in support of the "Certificate of Readiness" stating that all equipment, systems and controls are complete and ready for functional performance testing.

2. Testing Phase

- a. Provide skilled technicians tools, instrumentation, equipment and materials necessary to perform building envelope testing and building system FPTs under the observation of the CxP for specified equipment. 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. Assist the CxP in interpreting the monitoring data, as necessary.

- b. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxP, CM and A/E and retest the equipment.
- c. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions. O&M manuals are to be complete and approved for use during owner training.
- d. During construction, maintain as-built red line drawings for all drawings and final CAD as-builts for Contractor-generated coordination drawings. Update as-builts as required after completion of commissioning (excluding deferred testing).
- e. Provide training of the Owner's operating staff using expert qualified personnel.
- f. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.
- g. Execute seasonal or deferred functional performance testing, witnessed by the CxP.
- h. Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

G. Mechanical Contractor:

The responsibilities of the HVAC Mechanical Contractor, during Construction Phases **in addition to those listed in Paragraph G** of this section above are:

1. Provide start-up for all HVAC equipment, except for the building automation control system.
2. Assist and cooperate with the TAB Contractor and CxP by:
 - a. Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
 - b. Including cost of sheaves and belts that may be required by TAB.
 - c. Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Providing an approved plug.
 - d. Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.
3. Install a P/T plug at each water sensor that is an input point to the control system.
4. List and clearly identify on the as-built drawings the locations of all airflow stations.
5. Notify the CM with adequate notice (≥ 5 days), who will notify the CxP, of time and date for start-up of each piece of equipment. Be responsible to notify the CM

ahead of time when commissioning activities not yet performed or not yet scheduled will delay construction.

H. Controls Contractor:

1. The commissioning responsibilities of the Controls Contractor, during Construction Phases **in addition to those listed in Paragraph G** of this section above are:
2. Sequences of Operation Submittals:
 - a. The Controls Contractor's submittals of control drawings shall include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the specifications. They shall include:
 - 1) An overview narrative of the system generally describing its purpose, components and function.
 - 2) All interactions and interlocks with other systems.
 - 3) Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable.
 - 4) Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included but will generally require additional narrative).
 - 5) Sequences for start-up, shut down, warm-up, cool-down, normal, unoccupied modes and optimal start and stop sequences.
 - 6) Capacity control sequences and equipment staging.
 - 7) Temperature and pressure control: setbacks, setups, resets, etc.
 - 8) Detailed sequences for all control strategies.
 - 9) Effects of loss of power at the general building level and at the local disconnect level and how the local controller and each piece of equipment will respond and response at power restoration and methods for reset.
 - 10) Special sequences upon equipment failure and standby functions.
 - 11) Sequences for all alarms and emergency shut downs.
 - 12) Seasonal operational differences and recommendations.
 - 13) Initial and recommended values for all adjustable settings, set points and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.

- 14) Schedules, if known.
3. Control Drawings Submittal: Submit detailed control drawings and control wiring diagrams and if requested block or logic diagrams of control programs for all commissioned equipment under BAS control. Update these drawings through the submittal and sequence review and approval process:
 - a. The control drawings shall have a table of contents and a key to all abbreviations (including all abbreviations in schematics and points list column headings and cell contents).
 - b. The control drawings shall contain graphic schematic depictions of all systems with each component, valves, dampers, actuators, coils, filters, fans, pumps, speed controllers, piping, ducting, etc., and each monitored or control point and sensor, all interlocks to other equipment, and include fan and pump cfm; gpm and horsepower by each element. List the location of remote points off the schematic, like static pressure sensors, outside air sensors, etc.
 - c. Panel wiring diagrams shall be included.
 - d. Network architecture drawing showing all controllers, workstations, printers, and other devices in a riser format and including protocols and speeds for all trunks.
 - e. Interface wiring diagrams shall be included.
 - f. 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.
 - g. Integrated drawings for all interfaces to packaged equipment control panels. Obtain a vector scan or CAD version of the ladder diagram or other wiring diagram for the equipment to be interfaced with. Incorporate this complete drawing into the control shop drawing that depicts the interface so that the result is one drawing that depicts the entire control circuit.
 - h. Provide a full points list with at least the following included for each point:
 - 1) Point abbreviation / name (names shall be pre-approved by Owner)
 - 2) Point type including all AI, AO, DI, DO, set points and calculated points
 - 3) Equipment the point is associated with
 - 4) Point description, including for DI points the method of indication (a fan status would state, "by motor CT" or a pump might state "by pump dP")
 - 5) Terminal or channel the point is landing on in the field panel
 - 6) Display unit (F, in WC, 1/0, %, Hz, etc.)
 - 7) Controller type
 - 8) Panel ID
 - 9) Panel physical location

- 10) Field device (temperature sensor, starter, contact, static tip, etc.)
 - 11) Comments column
 - 12) The Controls Contractor shall keep the CxP informed of all changes to this list during programming and setup.
- i. Room Schedule. A listing of all rooms shall be provided with at least the following information for each room: floor, room number, room name, air handler ID, air terminal tag ID and minimum and maximum cfm for both heating and cooling.
 - j. Valve schedule, including at least: valve tag, system tag (air handler or terminal), service (heating or cooling), action (2-way, 3-way), fail position, body style, size, close-off pressure, gpm or lb/hr, design Cv, actual Cv, design differential pressure (dP), actual dP, actuator type and comments.
 - k. Provide a set of building floor plans showing the location of all and controllers.
 - l. Sketches of all graphics screens for review and approval.
 - m. Graphic penetration tree listing all graphics screens at all points.
4. The Controls Contractor shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to functional performance testing. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:
- a. System name.
 - b. List of devices.
 - c. Step-by-step procedures for testing each controller after installation, including:
 - 1) Process of verifying proper hardware and wiring installation.
 - 2) Process of downloading programs to local controllers and verifying that they are addressed correctly.
 - 3) Process of performing operational checks of each controlled component.
 - 4) Plan and process for calibrating valve and damper actuators and all sensors.
 - 5) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
 - d. A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor or controller has "passed" and is operating within the contract parameters.

- e. A description of the instrumentation required for testing.
 - f. Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CxP and TAB Contractor for this determination.
5. Point-to-point Checkout:
- a. The point-to-point checkout shall include verification of each control point tied to a central control systems ability to be commanding, reporting and controlling according to its intended purpose. For each output, commands will be initiated and verified to be functioning by visually observing and documenting the status of the controlled device in the field (e.g., command lights or sound off, command cooling coil valve to full open, or command heating water pump off). For each input, the system or conditions will be perturbed to initiate the input response being tested and the response in the control system observed and recorded (e.g., high duct static pressure alarm). This input verification could be accomplished by “ohming” each wire or after communication is made, by unhooking the wire to the device and observing a failed communication with the proper point.
 - b. Dampers and valves shall be checked by driving them fully open and fully closed in the control system and confirming visually in the field that the device is in the commanded and feedback position and that linkages are secure, lubricated and moving without binding.
 - c. Points within and controlled by packaged equipment controllers do not require a point-to-point checkout, unless required in the manufacturer’s start-up and checkout procedures.
 - d. Point-to-point checkout will be documented for each input and output device, with technician’s initials certifying each device has been tested and calibrated on forms approved by the Commissioning Provider.
 - e. Tune PID loops and each control routine that requires tuning.
6. Alarms and Interlocks:
- a. Check each alarm with an appropriate signal at a value that will trip the alarm, confirming proper logic.
 - b. Confirm that alarms enunciate in the BAS alarm log as well as giving an indication on the graphic screen of the equipment in alarm.
7. Prior to air and water balance the Controls Contractor shall perform the following tests and checks:
- a. With the air handler supplying adequate air and the VAV boxes operating, run a global VAV box flow test that checks each box at maximum, partial and zero damper and reheat valve positions. Confirm that each damper and valve goes to max open and closed and the expected water and airflow and temperature change are observed, confirming no valve leak-by.
 - b. Run an automatic scan of all devices on the network to identify any communication and addressing problems. These tests shall identify any boxes that are having communication problems, address problems and flow or actuator problems. A full printout of the results shall be submitted to the Balancing Contractor and Commissioning Provider for review prior to balancing.
8. Sensor Calibrations: The Contractor shall calibrate and adjust sensors according to the requirements below.

- a. Field-installed temperature, relative humidity, CO, CO₂, air and hydronic and air flow and pressure sensors shall be checked in the field for proper calibration and adjusted as necessary. This requirement applies to all central building automation or control system sensors. Sensors, wiring, transducers and controllers installed together in an equipment unit at the factory with calibration certification provided need not be field calibrated.
- b. Calibrations will be documented on forms approved by the Commissioning Provider which will indicate any adjustments made.
- c. Calibration shall include verifying that the sensor location is away from causes of erratic sensing (in stratified air flow, touching coils, thermostats affected from air leakage within walls, external heat sources, etc.).
- d. Calibration check shall be made by taking a reading with a calibrated handheld instrument with a total instrument accuracy equal to or greater than the accuracy of the sensor being checked. Total handheld accuracy is calculated by squaring the probe sensor accuracy and squaring the transducer accuracy, then summing the two results and taking the square root of the sum. Thermistor temperature sensors shall not be calibrated with handheld thermocouple instruments because thermocouples are too inaccurate.
- e. Sensors will be checked near the middle of their expected normal operating range. Temperature sensors will be checked against a handheld reading near enough to the sensor to provide a reliable reading.
- f. Sensor readings outside the following tolerances compared to the handheld reading shall have an offset installed or sensor replaced.
 - 1) Temperatures: Cooling coil, chilled and condenser water, outside air, duct air, space: +/- 0.2F.
 - 2) Temperatures: Air handler averaging: +/- 0.6F.
 - 3) Temperatures: Critical spaces: +/- 0.1F.
 - 4) Temperature: Sensor pairs for differences: +/- 0.0F.
 - 5) Temperatures: Heating and domestic hot water: +/- 0.5F.
 - 6) Dew point temperature: +/- 0.3F.
 - 7) Relative humidity: +/- 2% RH of reading.
 - 8) Room or building pressure: +/- 0.01 " WC.
 - 9) Duct air and hydronic pressure: +/- 0.5% of reading.
- g. Airflow Sensors: Air terminal flow sensors are calibrated during the air balancing process. Factory calibrated air handler flow stations have their calibration checked (but not calibrated) by the air balancer comparing a simultaneous duct, coil or filter traverse and a fan curve plot with the station reading. When the balancer's data is within 20% of the flow station reading, the flow station is deemed to be reading accurately. If the balancer's data is more than 20% off, further investigation shall be conducted.
- h. Hydronic Flow Sensors: Factory calibrated hydronic flow sensors are checked for accuracy by first confirming that the installer followed all the manufacturer's installation and set-up instructions. Then, the balancer compares the flow sensor reading with two or more simultaneous pump, triple duty or balancing valve, coil or chiller bundle pressure drop plot or strap-on ultrasonic or electro-magnetic flow meter. When the average of the balancer's data is within 20% of the flow sensor reading, the flow sensor is deemed to be reading accurately. If the balancer's data is more than 20% off, further investigation shall be conducted.

9. Prior to functional testing, review the functional test procedures provided by the Commissioning Provider, run the equipment through the test procedures (not just in the control logic) and confirm the equipment and system is ready for and will pass functional testing with the Commissioning Provider and sign a copy of the test form attesting to this activity.
10. List and clearly identify on the as-built duct and piping drawings the locations of all static and differential pressure sensors (air, water and building pressure).
11. Much of the testing will be accomplished using the building automation system. The system graphics shall be complete and approved prior to active testing, so the graphics can be used for and verified during testing.
12. The Controls Contractor shall keep the CxP informed of all changes to the point list during programming and setup.
13. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal. Follow specified MIT protocols for as-built formatting.
14. Assist and cooperate with the TAB Contractor in the following manner:
 - a. Meet with the TAB Contractor prior to beginning TAB and review the TAB plan to determine the capabilities of the control system toward completing TAB. Provide the TAB any needed unique instruments for setting terminal unit boxes and instruct TAB in their use (handheld control system interface for use around the building during TAB, etc.).
 - b. For a given area, have all required pre-functional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CxP prior to TAB.
 - c. Provide a qualified technician to operate the controls to assist the TAB Contractor in performing TAB or provide sufficient training for TAB to operate the system without assistance.
15. Assist and cooperate with the CxP in the following manner:
 - a. Using a skilled technician who is familiar with this building, execute the FPTs of the controls system as specified for the Controls Contractor. Assist in the functional testing of all equipment specified. Provide two-way radios during the testing.
 - b. Execute all control system trend logs specified.
16. Provide a signed and dated certification to the CM who will forward to the CxP upon completion of the checkout of all controlled devices, 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.
17. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as requested by the CxP to demonstrate system operation.

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18. 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).
- I. TAB Contractor:
 1. The commissioning responsibilities of the TAB Contractor, **in addition to those listed in Paragraph G** of this section above are [refer to Specification Section TBD for additional scope]:
 2. Submit the outline of the TAB plan and approach for each system and component to the CxP and the Controls Contractor six weeks prior to starting the TAB. This plan will be developed after the TAB has some familiarity with the control system.
 3. The submitted plan will include:
 - a. Certification that the TAB Contractor has reviewed the construction documents and the systems with the design engineers and Contractors to sufficiently understand the design intent for each system.
 - b. 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.
 - c. Discussion of what notations and markings will be made on the duct and piping drawings during the process.
 - d. Final test report forms to be used.
 - e. Detailed step-by-step procedures for TAB work for each system and issue: terminal flow calibration (for each terminal type), diffuser proportioning, branch/sub main proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions, etc.
 - f. List of all airflow, water flow, sound level, system capacity and efficiency measurements to be performed and a description of specific test procedures, parameters, formulas to be used.
 - g. 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.).
 - h. The identification and types of measurement instruments to be used and their most recent calibration date.
 - i. Specific procedures that will ensure that both air and water sides are operating at the lowest possible pressures and provide methods to verify this.
 - j. Confirmation that TAB understands the outside air ventilation criteria under all conditions.
 - k. Details of whether and how minimum outside air cfm will be verified and set, and for what level (total building, zone, etc.).

- l. Details of how Lab pressure control will be checked.
 - m. Details of methods for making any specified coil or other system plant capacity measurements.
 - n. Details of any TAB work to be done in phases (by floor, etc.), or of areas to be built out later.
 - o. Details regarding specified deferred or seasonal TAB work.
 - p. Details of any specified false loading of systems to complete TAB work.
 - q. Details of all exhaust fan balancing and capacity verifications, including any required room pressure differentials.
 - r. Details of any required interstitial cavity differential pressure measurements and calculations.
 - s. 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).
 - t. Plan for formal progress reports (scope and frequency).
 - u. Plan for formal deficiency reports (scope, frequency and distribution).
- 4. The TAB field technicians shall keep a running log of events and issues. Submit hand-written reports of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests to the CxP and CM at least twice a week.
 - 5. Communicate in writing to the Controls Contractor all set point and parameter changes made or problems and discrepancies identified during TAB that 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 CxP. 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 CxP with any requested data gathered, but not shown on the draft reports.
 - 8. Provide a final TAB report for the CxP with details, as in the draft.
 - 9. Conduct functional performance tests and checks on the original TAB as specified.

1.10 MEETINGS

A. Kick-Off Meeting:

- 1. As early as possible, CM will schedule commissioning Kick-Off meetings with entire commissioning team in attendance. CxP will present preliminary

commissioning plan at this meeting. The CxP will distribute meeting minutes to all parties.

B. Miscellaneous Meetings:

1. Other meetings will be planned and conducted by the CxP as construction progresses. These meetings shall cover coordination, deficiency resolution and planning issues with particular Subs. CxP will plan these meetings through CM and the CxP will distribute meeting minutes to all parties.

1.11 REPORTING

- A. The CxP will provide regular reports to the CM, with increasing frequency as construction and commissioning progresses.
- B. The CxP 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.

1.12 SUBMITTALS

- A. The CxP will review submittals related to the commissioned equipment as it relates to the commissioning process, to the functional performance of the equipment and adequacy for developing test procedures. This review is intended primarily to aid in the development of functional testing procedures.
- B. The CxP 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.
- C. The O&M manuals and as-builts are the responsibility of the Contractor, though the CxP will review.

1.13 TESTING REQUIREMENTS

- A. Specific functional testing requirements are provided for a majority of systems found in the project. From these requirements, the CxP will develop step-by-step procedures to be executed by the Subs. Additional testing requirements shall be provided by the CxP for those systems not detailed herein. The test requirements for each piece of equipment or system contain the following:
 1. The Contractors responsible to execute the tests.
 2. A list of the integral components being tested.
 3. Pre-functional checklists associated with the components.
 4. Functions and modes to be tested.
 5. Required conditions of the test for each mode.
 6. Special procedures.
 7. Required methods of testing.
 8. Required monitoring.
 9. Acceptance criteria.
 10. Sampling strategies allowed.

- B. The testing requirements specified for commissioning are in addition to and do not replace any testing requirements specified elsewhere.

1.14 TESTING PREREQUISITES

- A. The following applicable generic prerequisite checklist items are required to be completed and checked off by the Contractors prior to functional testing:
 1. All related equipment has been started up and start-up reports and pre-functional checklists submitted and approved.
 2. "Certificate of Readiness" is submitted and signed by the installing Contractor and CM.
 3. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final set points and schedules with debugging, loop tuning and sensor calibrations completed. Controls Contractor to sign and date when ready.
 4. Piping system flushing is complete and required report approved.
 5. Water treatment system is complete and operational.
 6. Vibration control report is approved (if required).
 7. Test and balance (TAB) complete and approved for the HVAC air and water systems.
 8. All A/E punchlist items for this equipment corrected.
 9. Functional test procedures reviewed and approved by installing Contractor.
 10. The test procedures from the CxP have been executed on the equipment and equipment passed with variances noted and the test form signed by the Contractor attesting to this pre-testing.
 11. Required pre-test trend reports for this equipment have been developed and submitted to the CxP for review and approval.
 12. Safeties and operating ranges reviewed by the CxP.
 13. Test requirements and sequences of operation attached.
 14. Schedules and set points attached.
 15. False loading equipment, system and procedures ready.
 16. Crankcase heaters have been on long enough for immediate startup.
 17. Sufficient clearance around equipment for servicing.
 18. Record of all values of pre-test setpoints that may be changed to accommodate testing has been made and a check box provided on the test form to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).

1.15 TEST METHODS AND MONITORING

1. Manual test method is a method of testing that requires visual inspection of the device performing as intended.
2. Demonstration test method is used when verification of equipment requires the CxP to witness and the Contractor to prove actual performance; i.e., TAB Contractor must demonstrate air velocities, etc.
3. Monitoring is a method of testing as a stand-alone method or to augment manual testing.
 - a. 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 CxP's request, the Controls Contractor shall trend up to 20% more points than listed herein at no extra charge.
 - b. Provide data electronically (Microsoft Excel) in 15-minute intervals for all analog hardware and software points.

1.16 TEST EQUIPMENT

- A. The Division Contractor shall provide all testing equipment required to perform startup, initial checkout and functional performance testing.
- 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.
- C. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the Specifications.

1.17 PREFUNCTIONAL CHECKLISTS, START-UP AND INITIAL CHECKOUT

- A. The following procedures apply to all equipment to be commissioned.
- B. Execution of Pre-Functional Checklists
 1. Pre-Functional Checklists (PFCs) are required to verify that the equipment and systems are hooked up and operational. It ensures that functional performance testing may proceed without unnecessary delays. Each piece of equipment shall receive full pre-functional checkout. No sampling strategies are to be used. The PFCs for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.
 2. Prior to startup, the execution of the PFCs are directed and executed by the Subs.
 3. Only individuals that have direct knowledge of the piece of equipment for which the PFC is being filled shall initial or check off items on that sheet. It is not acceptable for witnessing supervisors to fill out these forms.
 4. The CxP will approve pre-functional checklist completion by auditing the completed pre-functional checklist reports and by direct site observation.
- C. Start-up and Initial Checkout Plan:

1. The following procedures apply to all equipment requiring a start-up plan as indicated in Section 1.8 "Systems to be commissioned" matrix.
 2. The primary role of the CxP in this process is to verify 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 for each system.
 3. The Subcontractor responsible for the purchase of the equipment shall develop the full start-up plan by combining the manufacturer's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan shall include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.
 4. As a minimum, the start-up plan shall consist of the following:
 - a. The manufacturer's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block at the end.
 - b. The manufacturer's field checkout sheets.
 5. The Subcontractor shall submit the full startup plan to the CxP for review.
 6. The CxP will review the procedures and the format for documenting them.
- D. Sensor and Actuator Calibration:
1. 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 approved methods. Sensors provided with calibration certification need not be field calibrated.
 2. 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.
- E. Valve and Damper Stroke Setup and Check:
1. For all valve and damper actuator positions checked, verify the actual position against the BAS readout.
- F. Execution of Startup:
1. The Subs and vendors shall execute startup, complete the start-up checklist(s), and provide the materials to the prime Contractor. The prime Contractor will provide the CxP with a signed and dated copy of the completed start-up checklists.

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

G. 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 CxP within two days of checklist completion.
2. The CxP will review the report. When satisfactorily completed, the CxP will recommend 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.

1.18 FUNCTIONAL PERFORMANCE TESTING & INTEGRATED SYSTEMS TESTING

- A. This sub-section applies to all commissioning functional performance and integrated systems testing for all divisions.

- B. The parties responsible to execute each test are listed with each test.

C. FPT Objectives and Scope:

1. The Functional Performance Testing (FPT) shall demonstrate that each system is operating according to the 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 shall be identified and corrected, improving the operation and functioning of the systems.
2. Each system shall 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.

D. Development of Test Procedures:

1. Before test procedures are written, the CxP 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.
2. The CxP shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each Sub or vendor responsible to execute a test shall provide assistance to the CxP in developing the procedures (answering questions about equipment, operation, sequences, etc.). Prior to execution, the CxP shall provide a copy of the test procedures to the Sub(s) who shall review the tests for feasibility, safety, equipment and warranty protection.

3. The CxP shall review Owner-contracted, factory testing or other required Owner tests which the CxP is not responsible to oversee, including documentation format, and shall determine what further testing or format changes may be required to aid in the commissioning effort. Redundancy of testing shall be minimized.
4. The test procedure forms developed shall include (but not be limited to) the following information:
 - a. System and equipment or component name(s)
 - b. Equipment location and ID number
 - c. Date
 - d. Project name
 - e. Participating parties
 - f. A copy of the specification section describing the test requirements
 - g. A copy of the specific sequence of operations or other specified parameters being verified
 - h. Formulas used in any calculations
 - i. Required pre-test field measurements
 - j. Instructions for setting up the test
 - k. Special cautions, alarm limits, etc.
 - l. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format
 - m. 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
 - n. A section for comments
 - o. Signatures and date block

E. Test Methods:

1. Functional performance testing and verification may be achieved by manual testing, monitoring, either or both as indicated in the procedure.
 - a. Manual testing (persons manipulate the equipment and observe performance)
 - b. Monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone data loggers. The CxP may substitute specified methods or require an additional method to be executed, other than what was specified.
2. Simulated Conditions:
 - a. Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
3. Overwritten Values:
 - a. 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.

4. Altering Set Points:
 - a. Rather than overwriting sensor values, and when simulating conditions is difficult, altering set points to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55F, when the outside air temperature is above 55F, temporarily change the lockout set point to be 2F above the current outside air temperature.
5. Setup:
 - a. 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.
6. Sampling:
 - a. The recommended sampling rates are specified with each type of equipment in the testing sections of this specification. It is noted that no sampling by Subs is allowed in PFC execution. The following is an example of how multiple pieces of equipment that are identical may be tested.
 - 1) For example, randomly test at least 20% of each group of identical equipment. In no case test less than (3) units in each group. This 20%, or (3), constitute the "first sample."
 - 2) If 10% of the units in the first sample fail the functional performance tests, test another 20% of the group (the second sample).
 - 3) If 10% of the units in the second sample fail, test all remaining units in the whole group.
 - b. If at any point, frequent failures are occurring and testing is becoming more troubleshooting than verification, the CxP shall stop the testing and require the responsible Sub to perform and document a checkout of the remaining units, prior to continuing with functionally testing the remaining units.

F. Coordination and Scheduling:

1. The Subs shall provide sufficient notice to the CxP and CM regarding their completion schedule for the startup of all equipment and systems. The CxP will schedule FPTs through the CM and affected Subs. The CxP shall direct, witness and document the FPTs and ISTs of all equipment and systems. The Subs shall execute the tests.
2. In general, FPTs are conducted after PFCs and startups have been satisfactorily completed. The control system is sufficiently tested and approved by the CxP before it is used for TAB or to verify performance of other components or systems.

G. Problem Solving:

1. The CxP will recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the CM, Subs and A/E.

H. IST Objectives and Scope:

1. Integrated systems tests shall be performed for all systems to be commissioned. Tests shall begin only after pertinent FPTs have been successfully completed. Tests shall prove integrated response to all modes of the sequences of operation, and shall verify all other relevant contract requirements. Tests shall begin with equipment or components and shall progress through subsystems to complete systems. Upon failure of any integrated systems test, the Contractor shall correct all deficiencies in accordance with the applicable contract requirements. The test shall then be repeated until it has been completed with no errors.

2. Integrated Systems Testing Details

a. Testing Overview and General Requirements

- 1) Purpose: The purpose of the integrated systems testing is to determine the total system operation and response to normal, emergency and "What If" conditions which may arise during daily operations.

b. Prerequisites

- 1) All equipment and systems testing per Divisions 21, 22, 23, 25 and 26 are complete and approved.
- 2) The BAS will be used to record the system data and the dynamic step response data. Where BAS points are not available manually recorded parameters will be acceptable.
- 3) The balancing of all related components and installed systems will be complete and test results shall be available.

c. Procedure

- 1) Conduct testing as described in the final test report.
- 2) The effects on the systems relating to the various operational and failure conditions will be monitored, recorded and response times noted. The variables will be measured on a real time basis and utilizing the collected data fine tuning adjustments to the systems will be implemented.
- 3) All test results will be presented in both graphic form and trend printout and provided in two electronic data file formats (CSV and PDF). The Controls Contractor will provide the trending data from their system.

I. List of Integrated System Tests, as applicable

1. Facility Power Fail Operations
2. Fire Alarms

1.19 BUILDING ENVELOPE MOCK-UPS AND TESTING

- A. Refer to specification Section 019117 for Building Envelope testing requirements.

1.20 BAS EVALUATION

- A. The CxP shall review all BAS graphic screens for correctness and completeness. This includes verifying, but is not limited to, the following:
 1. Accuracy of graphics to installed system. (*Does it accurately depict the system and operation as provided?*)
 2. Accuracy of sensor readings. (*I.e. Do the readings correspond to the correct sensor in the field and are those readings accurate?*)
 3. Existence of active alarms or errors on the system. (**Verify alarm delays**)
 4. Consistency of graphic pages and links. (*Are there the same points/ links on similar pages?*)
 5. Correctness and completeness of page links. (*Links take you to correct location and that location has all the required information.*)

1.21 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

- A. Documentation:

1. The CxP shall witness and document the results of all FPTs using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the CM and Subs for review.

- B. Non-Conformance:

1. The CxP will record the results of the FPT on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the CM on an agreed upon non-compliance form. This form may be the CxP's master deficiency and resolution log.
2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the CxP. In such cases the deficiency and resolution will be documented on the procedure form.
3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the CxP will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues.
4. At the CxP's discretion, if large numbers or repeated deficiencies are encountered, the Contractor shall test and troubleshoot all remaining systems at issue on their own before further functional testing of that system with the CxP will resume.
5. As tests progress and a deficiency is identified, the CxP 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 CxP documents the deficiency and the Sub's response and intentions and they go on to another test or sequence. The Sub corrects the deficiency, signs the non-compliance form or other approved document certifying that the equipment is ready to be retested and sends it back to the CxP.
 - 2) The CxP reschedules the test and the test is repeated.
 - 3) If the deficiency is identified during the retest, the cost for that retest, as well as any other retest effort, will be as indicated below in Item 8 – Cost of Retesting.
- 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 on the non-compliance form 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 Owner and the CxP.
 - 3) The CxP documents the resolution process.
 - 4) Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the non-compliance form or other approved document and provides it to the CxP. The CxP reschedules the test and the test is repeated. If the deficiency is identified during the retest, the cost for that retest, as well as any other retest effort, will be as indicated below in Item 8 – Cost of Retesting.
6. The Contractor shall respond in writing to the CxP 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 CxP retains the original non-conformance forms until the end of the project.
8. Any required retesting by any Contractor shall not be considered a justified reason for a claim of delay or for a time extension by the prime Contractor.
9. 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 CM.
 - b. The added time for the CxP and CM to direct any retesting required because a specific start-up test item, reported to have been successfully completed by the installing Contractor, but determined during FPTs or ISTs to be faulty, may be back charged to the Contractor responsible for the misinformation or deficiency.

C. Approval:

1. The CxP notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made later after review by the CxP and by the CM, if necessary. The CxP 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 CxP and the Contractor.

1.22 DEFERRED TESTING

A. Unforeseen Deferred Tests:

1. 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:

1. During the Testing Phase, seasonal testing (tests delayed until weather conditions are closer to the system's design) shall be completed as part of this contract. The CxP shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the appropriate Subs, with facilities staff and the CxP witnessing. Any final adjustments to the O&M manuals and as-builts due to the testing will be made.
2. Test procedures indicate cooling season, heating season or both. If there is no season indicated, there is no special seasonal test required and the test can be executed during any season, if condition simulation is appropriate. Where "design" is indicated in the procedure, it means that the season is within 5°F of the ASHRAE 2-1/2% design criteria or 95% of the loading design.
3. NOTE: Functional performance tests on respective seasonal equipment shall be executed during both the heating/cooling seasons (design days), as well as shoulder seasons (changeover conditions).

1.23 WRITTEN WORK PRODUCTS

- A. The commissioning process generates a number of written work products described in the Specifications. Below is a list of all the formal written work products and who is responsible to create them. In summary, the written products are:

Product	Developed By
1. Commissioning meeting minutes	CxP
2. Commissioning schedules	CM with input from the CxP
3. Complete commissioning plan	CxP
4. Equipment documentation submittals	Subcontractors and vendors
5. Sequence clarifications	Subcontractors and A/E as needed
6. Basis of design documentation	A/E
7. Equipment startup and initial checkout plan	Subcontractors and vendors, review by CxP
8. Write PFCs	CxP with primary input from Subcontractors

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9. Executed PFCs	Subs
10. TAB plan	TAB Subcontractor with verification by CxP and Owner
11. Final TAB report	TAB with verification by CxP and Owner
12. Certificates of Readiness	GC and Installing Subs
13. Write functional performance tests	CxP with primary input from Subcontractors
14. Executed functional performance tests	Subcontractors with verification by CxP
15. Write integrated systems testing protocols	CxP with input from Subcontractors and A/E
16. Executed integrated systems testing	Subcontractors with verification by CxP
17. Corrective action tracking log (deficiencies)	CxP
18. Commissioning progress record	CxP
19. Deficiency reports	CxP
20. Owner Training Plan	Subcontractors approved by CxP
21. O&M manuals	Subcontractors approved by CxP
22. Warranty List	Subcontractors approved by CxP
23. Systems Manual	CxP
24. Final commissioning report	CxP

2.0 MECHANICAL (HVAC) TESTING REQUIREMENTS

The following sections depict minimum requirements for the functional performance and integrated system testing executed for this facility. It is up to the CxP to determine how the following is accomplished and whether additional testing is required based on the final design.

2.1 AIR HANDLING UNITS – RECIRCULATING

A. Parties Responsible to Execute Functional Test

1. Controls Contractor: Operate the controls to activate the equipment.
2. CxP: To witness, and document testing.
3. TAB Contractor to verify air and water flows.
4. Mechanical Contractor to fix any problems.
5. Unit Manufacturer’s Representative (as required).

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

1. Chilled water system
2. Hot water heating or steam system
3. Controls
4. Associated supply, transfer, return and exhaust fans
5. Terminal units

C. Prerequisites:

1. The applicable prerequisite checklist shall be signed off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists before the beginning of functional testing.

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

Function/Mode	Test Method	Seasonal Test
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
2. Preheat coil temperature control functions	Both	Heating
3. Economizer functions	Both	Cooling
4. Supply fan, return fan and exhaust fan interlocks	Either	
5. Chilled water valve control properly sequenced	Both	Cooling
6. Damper interlocks and correct modulation in all modes, including fire and smoke dampers and CO ₂ control	Manual	
7. Temperature difference across heating and cooling coils	Manual	Both
8. Smoke detectors	Manual	
9. Verify TAB reported fan cfm with control system reading	Manual	
10. All alarms and safeties (low limits, high static, freeze stat, etc.)	Manual	
11. Supply and return fans static pressure and volume control	Monitoring	Design

Function/Mode	Test Method	Seasonal Test
12. Sensor and actuator calibration checks on: SAT, MAT, OSAT, Co ₂ , economizer and RA dampers and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure set point, with an inclined manometer)	Manual	
13. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Testing Phase is complete. Provide CxP with all requested data until approved.	Monitoring	Both
14. Verify control strategies, schedules and set points to be reasonable and appropriate	Review	

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

1. None.

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

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

2.2 AIR HANDLING UNITS – 100% OUTSIDE AIR AND EXHAUST

A. Parties Responsible to Execute Functional Test:

1. Controls Contractor: Operate the controls to activate the equipment.
2. CxP: To witness and document testing.
3. TAB Contractor to verify airflows.
4. Mechanical Contractor to make any adjustments.
5. Unit Manufacturer’s Representative (as required).

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

1. Chilled water system
2. Steam system
3. Associated supply and exhaust fan systems
4. Supply and exhaust terminal units
5. Controls

C. Prerequisites:

1. The applicable pre-functional checklist items shall be signed off prior to functional testing. The commissioning agent may spot-check misc. items and calibrations on the pre-functional checklists before the beginning of functional testing.

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

Function/Mode	Test Method	Seasonal Test
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
2. Supply air, and reset temp. control functions	Both	
3. Supply and exhaust fan interlocks	Either	
4. Damper interlocks and correct modulation in all modes, including fire and smoke dampers	Manual	
5. Cooling, and heating controls	Manual	
6. Smoke alarm and any actions initiated from the fire alarm control panel	Manual	
7. Verify TAB reported SF cfm with control system reading	Manual	
8. All alarms and safeties (low limits, high static, freeze stat, etc.)	Manual	
9. Supply and exhaust fans VFDs and static pressure and volume control	Manual	
10. Sensor and actuator calibration checks on: SAT and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure set point, with an inclined manometer)	Manual	
11. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Testing Phase is complete. Provide CxP with all requested data until approved.	Monitoring	Both
12. Verify control strategies, schedules and set points to be reasonable and appropriate.	Review	

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

1. None OR Verify ventilation balancing and relative pressurization of spaces.

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

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

2.3 EXHAUST FANS

A. The testing requirements apply to the following fans

1. Hood exhaust
2. Specialty exhaust
3. Miscellaneous exhaust

B. Parties Responsible to Execute Functional Test

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

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- C. Integral Components or Related Equipment Being Tested: Pre-functional checklists must be complete for all of the components listed below prior to performing this functional test.
 - 1. Controls
 - 2. Terminal equipment
- D. Prerequisites:
 - 1. The applicable prerequisite checklist items shall be signed off prior to functional testing. The commissioning agent may spot-check misc. items and calibrations on the pre-functional checklists before the beginning of functional testing.
- E. Functions/Modes Required To Be Tested, Test Methods:

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

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

2.4 SUPPLY AND EXHAUST FANS

- A. The testing requirements apply to the following fans:
 - 1. Atrium Intake and Smoke Exhaust System
 - 2. Return Air Systems
 - 3. Transfer Air Systems
- B. Parties Responsible to Execute Functional Test
 - 1. Controls Contractor: Operate the controls to activate the equipment.
 - 2. CxP: To witness and document testing.
 - 3. TAB Contractor to verify airflows.
 - 4. Mechanical Contractor to make any adjustments.
- C. Integral Components or Related Equipment Being Tested: Pre-functional checklists must be complete for all of the components listed below prior to performing this functional test.

- 1. None.

D. Prerequisites:

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

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

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

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

- 1. None.

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

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

2.5 TERMINAL UNITS TEST

A. Parties Responsible to Execute Functional Test:

- 1. Controls Contractor: Operate the controls to activate the equipment.
- 2. CxP: To witness and document testing.
- 3. Mechanical Contractor to make any adjustments.
- 4. TAB Contractor to verify flow rates and pressure relationships between spaces.

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

- 1. Constant volume and VAV boxes w/and w/o reheat coils (supply and exhaust)
- 2. Laboratory supply and exhaust flow controls
- 3. Fan coil units (FCU, FCW, FCH, FCA)
- 4. Radiation (FTR)
- 5. Chilled Beams
- 6. Unit heaters (UH, CUH, RR, PR)
- 7. In duct heating coils (RHC)

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- 8. Return air systems
- 9. Heat Exchanger and Pumps (HW)

C. Prerequisites:

- 1. The applicable prerequisite checklist items shall be signed off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists before the beginning of functional testing.

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

Function/Mode	Test Method	Seasonal Test
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, warm-up, shutdown, unoccupied & manual modes and power failure and restoration. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with, including all damper, valve and fan functions.	Manual	
2. Sensor calibration checks on: SAT, zone air temperature, airflow, fume hood face velocities, differential pressure between rooms, damper position and other random checks (EMS readout against visual or hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure set point, with an inclined manometer)	Manual	
3. Device and actuator calibration and stroke checks for heating coil valves, air valves and dampers	Manual	
4. Verify control parameters and set points to be reasonable and appropriate by reviewing the full program of 5% of all the TUs with each other for consistency. Verify the max. and min. cfm set points of all tested TUs against the control drawing and TAB values. Verify other TU programming parameters such as K-factors, dead bands, set points, stroke times, etc.	Observation	
5. Verify proper operation of valve in both cooling and heating modes under occupied and unoccupied conditions.	Both	Both
6. Verify no hunting or significant overshoot by valves and dampers.	Either	
7. Verify by measurement, HCV positive shutoff (no leak-thru).	Manual	
8. All alarms (fan status, low limits, etc.)	Manual	
9. Verify that TU is maintaining space temperature and pressure set points and fans are being cycled as specified.	Monitoring	Both Design
10. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Testing Phase is complete. Group points by room.	Monitoring	Both

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

- 1. Laboratory supply and exhaust testing under all modes.

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

- 1. For the conditions, sequences and modes tested, the TU, integral components and related equipment respond to varying loads and changing conditions and

parameters appropriately as expected, as specified and according to acceptable operating practice.

2. Space temperature during occupied modes shall average within +/- 1°F of set point and always remain within 1°F of the ends of the dead band without excessive hunting of the coil valve or complaints of drafts or stuffiness from occupants.
3. Laboratory pressure relationship able to be maintained within specifications under changes in surrounding conditions during; fume hood sash adjustments, doors opening and closing and changing between unoccupied and occupied modes.

2.6 HYDRONIC (CHILLED WATER) SYSTEM TEST

A. Parties Responsible to Execute Functional Test:

1. Electrical Contractor
2. Controls Contractor: Operate the controls, as needed.
3. HVAC Mechanical Contractor or vendor: Assist in testing sequences.
4. CxP: To witness and document testing.
5. Balancing Contractor to verify flows.

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

1. This test would apply to the following hydronic systems:
 - a. Chilled water
 - b. Chilled Beam active and passive systems
 - c. Chilled Beam water/pumps
 - d. Distribution Equipment (AHU, AC, FCU, FCW, FCH, FCA)

C. Prerequisites:

1. The applicable prerequisite checklist shall be checked off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer before the beginning of functional testing.

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

Function/Mode	Test Method	Seasonal Test
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.	Manual	
2. Supply pump staging, bypass valve operation, VFD. VFD operation: modulation to minimum, control system PID, proportional band of speed vs. controlling parameter, verification of program settings, alarms, etc.	Both	

Function/Mode	Test Method	Seasonal Test
3. Check all alarms and safeties (high and low pressure and temperature, etc.), PRV and flow switch functions	Manual	
4. Sensor and actuator calibration checks on: pressure sensor controlling pump speed, mixing valve and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of the pressure set point, with a test gage).	Manual	
5. Constancy of differential pressure (pump control parameter)	Monitoring	
6. Temperature control and operation	Manual	
7. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Testing Phase is complete.	Monitoring	
8. Water treatment, pressure and temperature safeties and alarms.	Manual	
9. Verify schedules and set points to be reasonable and appropriate	Review	

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

1. None.

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

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

2.7 HYDRONIC (HOT WATER) SYSTEM

A. Parties Responsible to Execute Functional Test:

1. Controls Contractor: operate the controls, as needed.
2. HVAC Mechanical Contractor or vendor: assist in testing sequences.
3. CxP: to witness and document testing.

B. Integral Components or Related Equipment Being Tested:

1. This test would apply to the following systems:
 - a. Lab heating
 - b. Radiation heating
2. Heat exchangers
3. Pumps, AD, ET
4. VFD
5. Distribution Equipment (UH, CUH, RR, PR, RHC)

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

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

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

Function/Mode	Test Method	Seasonal Test
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
2. <u>Primary Side:</u> Capacity modulation and primary HW supply pumps.	Both	Heating
3. <u>Secondary Side:</u> Secondary WH supply pump staging, bypass valve operation, if no VFD and HWT reset. VFD operation: modulation to minimum, control system PID, proportional band of speed vs. controlling parameter, verification of program settings, alarms, etc.	Both	Heating
4. Check all alarms and safeties (high and low pressure and temperature, etc.), PRV and flow switch functions.	Manual	
5. Test each possible lead pump as lead pump. Test pump lockouts.	Manual	
6. <u>Heat Exchanger Temperature Control:</u> Verify steam pressures with startup report and manufacturer's recommendations.	Manual	
7. Sensor and actuator calibration checks on: HWST, HWRT, pressure sensor controlling pump speed, mixing valve and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of the pressure set point, with a test gage)	Manual	
8. Constancy of differential pressure (pump control parameter)	Monitoring	Heating
9. Verify schedules and set points to be reasonable and appropriate.	Review	

- E. Special Procedures (other equipment to test with, etc.; reference to function ID):
 1. False load system, if necessary.

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

2.8 STEAM SYSTEM TEST

A. Parties Responsible to Execute Functional Test:

1. Electrical Contractor
2. Controls Contractor: Operate the controls, as needed.
3. HVAC Mechanical Contractor or vendor: Assist in testing sequences.
4. CxP: To witness and document testing.
5. Balancing Contractor to verify flows.

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

1. This test would apply to the following systems:
 - a. High, medium, and low pressure steam
 - b. Steam radiation
2. Steam to hot water heat exchanger
3. Steam pressure reducing stations
4. Condensate return system and pumps
5. HW supply pumps
6. Water treatment and water makeup systems

C. Prerequisites:

1. The applicable prerequisite checklist shall be checked off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer before the beginning of functional testing.

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

Function/Mode	Test Method	Seasonal Test
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.	Manual	
2. Steam supply pressure reducing valve station control system.	Both	Heating
3. Check all alarms and safeties (high and low pressure and temperature, etc.), PRV	Manual	
4. Sensor and actuator calibration checks on: pressure sensor (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of the pressure set point, with a test gage).	Manual	
5. Safety Valve	Manual	
6. Trend all temperature, pressure, speed and control points from the start of functional performance testing until Testing Phase is complete.	Monitoring	Both
7. Pressure and temperature safeties and alarms.	Manual	
8. Verify schedules and set points to be reasonable and appropriate	Review	

Function/Mode	Test Method	Seasonal Test
9. Condensate return pump system pumps lead/lag	Manual	

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

1. Testing of steam pressure regulating safety valves.

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

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

2.9 FUEL OIL SYSTEM

A. Parties Responsible to Execute Functional Test:

1. Controls Contractor: Operate the controls to activate the equipment.
2. CxP: To witness and document testing.
3. Mechanical Contractor to make any adjustments.

B. Integral Components or Related Equipment Being Tested:

1. Emergency generator fuel oil day tank transfer systems.
2. Storage tank and FOP 1&2 pumping transfer systems

C. Prerequisites:

1. The applicable prerequisite checklist shall be checked off prior to functional testing. The commissioning agent may also spot-check miscellaneous items and calibrations on the pre-functional checklists before the beginning of functional testing.

D. Functions/Modes Required to be Tested, Test Methods:

Function/Mode	Test Method	Seasonal Test
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.	Manual	
2. Emergency generator day tank control	Manual	
3. Fuel oil transfer pump control	Manual	
4. Fuel oil leak detection	Manual	
5. Alarms and safeties	Manual	

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

2.10 CONTROL SYSTEMS TEST

- A. Parties Responsible to Execute Functional Test:
 - 1. Controls Contractor: Operate the controls to activate the equipment.
 - 2. CxP: To witness and document testing.
- B. Integral Components or Related Equipment Being Tested: Pre-functional tests must be complete for all of the components listed below prior to performing this functional test.
 - 1. This procedure applies to the following control systems:
 - a. Building automation system (BAS)
 - b. Fume hood control & laboratory control
 - c. HVAC and Exhaust systems
 - d. Atrium smoke management
 - e. Pneumatic air system
 - f. AHU and conference room CO2 sensing and control
 - g. Energy meters
 - h. Spectroscopy complete lab control sequences
 - 2. All pre-functional checklists of controlled equipment
- C. Prerequisites:
 - 1. The applicable prerequisite checklist shall be listed checked off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer before the beginning of functional testing.
- D. A significant part of the BAS functional testing requirements is the successful completion of the functional tests of equipment the BAS controls or interlocks with. Uncompleted equipment functional tests or outstanding deficiencies in those tests lend the required BAS functional testing incomplete.
- E. Integral or stand-alone controls are functionally tested with the equipment they are attached to, including any interlocks with other equipment or systems and thus are not covered under the BAS testing requirements, except for any integrated functions or interlocks listed below.

- F. In addition to the controlled equipment testing, the following tests are required for the BAS, where features have been specified:

Function/Mode	Test Method
MISC. FUNCTIONS	
1. All specified functions and features are set up, debugged and fully operable.	Verbal discussion of features
2. Power failure and battery backup and power-up restart functions	Demonstration
3. Specified trending and graphing features demonstration	See equipment trends
4. Global commands features	Demonstration
5. Security and access codes	Demonstration
6. Occupant over-rides (manual, telephone, key, keypad, etc.)	Demonstration
7. O&M schedules and alarms	Demonstration
8. Scheduling features fully functional and setup, including holidays	Observation in terminal screens or printouts
9. Included features not specified to be setup are installed (list)	Demonstration
10. Demonstrate functionality of field panels using local operator keypads and local ports (plug-ins) using portable computer/keypad	Demonstration of 100% of panels and 10% of ports
11. All graphic screens and value readouts completed	Demonstration
12. Set point changing features and functions	Done during equipment testing
13. Communications to remote sites	Demonstration
14. Sensor calibrations	Sampled during equipment tests
15. Final as-builts or redlines (per spec) control drawings, final points list, program code, set points, schedules, warranties, etc. per specs, submitted for O&Ms.	Observation
16. Verify that points that are monitored only, having no control function, are checked for proper reporting to BAS.	Observation
17. Optional Start/Stop Routine	Demonstration
18. Final room numbers programmed into system.	
19. Owner's standard point naming conventions used.	
20. Operator at central workstation able to view all points within the control system	Demonstration
21. Terminal units control including air flow and temperature	
INTEGRATED TESTS	
22. Fire alarm interlocks and response	Demonstration
23. Demand limiting (including over-ride of limiting)	Monitoring
24. Sequential staging ON of equipment	Either
25. All control strategies and sequences not tested during controlled equipment testing	Either
26. Other integrated tests specified in the contract documents	
27. Emergency power operation and return to normal power	
28. Fire protection and suppression systems	Demonstration
29. Pneumatic air system	
30. Energy Meters	

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

1. None OR Process line equipment is not fully defined at this time, additional testing of that equipment may be required at a later date and will be done using an hourly rate or by a fixed price should the scope be clearly defined.

- H. Acceptance Criteria (referenced by function or mode ID):
 - 1. For the conditions, sequences and modes tested, the BAS, integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

2.11 TEST AND BALANCE WORK (TAB) TEST

- 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. CxP: To witness and document testing.
- B. Integral Components or Related Equipment Being Tested: Pre-functional tests must be complete for all of the components listed below prior to performing this functional test.
 - 1. TAB water-side
 - 2. TAB air-side
 - 3. TAB equipment and systems
 - 4. TAB electrical
- C. Prerequisites
 - 1. The applicable prerequisite checklist items shall be checked off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer, before the beginning of functional testing.
- D. Purpose:
 - 1. The purpose of this test is to spot check the TAB work to verify that it was done in accordance with the contract documents and acceptable practice and that the TAB report is accurate.

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

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

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

1. None.

G. Required Monitoring:

1. None.

H. Acceptance Criteria (referenced by function or mode ID): Provided in footnote to test table above.

1. Failure of an item is defined as follows:

- a. For air flow of supply and return: a deviation of more than 10% of instrument reading
- b. 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)
- c. For temperatures: a deviation of more than 1°F
- d. For air and water pressures: a deviation of more than 10% of full scale of test instrument reading

I. Sampling Strategy for Identical Units: Described in test table above.

3.0 PLUMBING TESTING REQUIREMENTS

The following sections depict minimum requirements for the functional performance and integrated system testing executed for this facility. It is up to the CxP to determine how the following is accomplished and whether additional testing is required based on the final design.

3.1 PLUMBING WATER SYSTEM

A. Parties Responsible to Execute Functional Test:

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

B. Integral Components or Related Equipment Being Tested:

- 1. This procedure applies to the following systems:
 - a. Hot water heaters (heaters, mixing valves)
 - b. Recirculating pumps

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

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

Function/Mode	Test Method
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual

Function/Mode	Test Method
2. Verify schedules and set points to be reasonable and appropriate	Review
3. Mixing valve operation and temperature control	Either
4. Sensor calibration checks on hot water temperature	Manual

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

1. None.

F. Required Monitoring:

1. None.

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

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

3.2 LAB WASTE PUMPS

A. Parties Responsible to Execute Functional Test:

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

B. Integral Components or Related Equipment Being Tested:

1. This procedure applies to the following systems:
 - a. Lab Waste Transfer Pumps

C. Prerequisites:

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

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

Function/Mode	Test Method
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual
2. Verify schedules and set points to be reasonable and appropriate	Review

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

1. None.

F. Required Monitoring:

- 1. None.

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

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

4.0 FIRE PROTECTION TESTING REQUIREMENTS

The following sections depict minimum requirements for the functional performance and integrated system testing executed for this facility. It is up to the CxP to determine how the following is accomplished and whether additional testing is required based on the final design.

4.1 SPRINKLER SYSTEMS

A. Parties Responsible to Execute Functional Test:

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

B. Prerequisites:

- 1. The applicable prerequisite checklist items shall be checked off prior to testing. The commissioning agent may also spot-check misc. items and calibrations on the checklists previously completed by the installer before the beginning of testing.

C. Functions/Modes Required To Be Tested and Test Methods:

Function/Mode	Test Method
1. Test per NFPA	Observation

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

- 1. Test per NFPA 13.

E. Required Monitoring:

- 1. None.

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

- 1. For the conditions as tested, equipment responds appropriately as expected, as specified and according to acceptable operating practice.

G. Sampling Strategy for Identical Units:

- 1. No sampling in test, but CxP is required to witness enough to be confident that proper procedures are followed.

5.0 ELECTRICAL TESTING REQUIREMENTS

The following sections depict minimum requirements for the functional performance and integrated system testing executed for this facility. It is up to the CxP to determine how the following is accomplished and whether additional testing is required based on the final design.

5.1 PROTECTIVE DEVICE SETTING

- A. Parties Responsible to Execute Functional Test:
 - 1. Electrical Contractor
 - 2. CxP: To witness and document testing.

- B. Integral Components or Related Equipment Being Tested: Pre-functional tests must be complete for all of the components listed below prior to performing this functional test.
 - 1. Breaker trip settings for all adjustable trip type breakers
 - 2. This procedure applies to the following systems:
 - a. All distribution systems
 - b. Unit substations

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

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

Function/Mode	Test Method
General 1. Review breaker settings per the short circuit protection study.	Manual

- E. Acceptance Criteria (referenced by function or mode ID):
 - 1. System is in compliance when trip settings are observed to be coordinated with report recommendations.

5.2 EMERGENCY GENERATOR TEST

- A. Parties Responsible to Execute Functional Test:
 - 1. Vendor Support Representative
 - 2. Electrical Contractor
 - 3. CxP: To witness and document testing.

- B. Integral Components or Related Equipment Being Tested: Pre-functional tests must be complete for all of the components listed below prior to performing this functional test.
 - 1. Generator Motor
 - 2. Generator Cooling System
 - 3. Generator Fuel System
 - 4. Phase Rotation

- C. Prerequisites:
 - 1. The applicable prerequisite checklist shall be checked off prior to functional testing. The commissioning agent may also spot-check misc. items and

calibrations on the pre-functional checklists previously completed by the installer before the beginning of functional testing.

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

Function/Mode	Test Method
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, and remote annunciation. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.	Manual
2. Stimulate power outage & subsequent automatic transfer switches operation(s)	Manual
3. Generator start capability upon signal from ATS upon loss of utility power	Manual
4. Check all alarms and annunciators local and remote and remote	Manual
5. Demonstrate interior of enclosure operational, i.e., lighting, battery chargers, etc.	Manual
6. Demonstrate proper functioning of governor and regulator	Manual
7. Verify operation of all emergency lighting, mechanical equipment, and elevators from generator power and restart upon re-energizing normal power.	Observation

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

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

5.3 AUTOMATIC TRANSFER SWITCH(ES) TEST

A. Parties Responsible to Execute Functional Test:

1. Vendor Support Representative
2. Electrical Contractor
3. CxP: To witness and document testing.
4. Balancing Contractor to verify flows.

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

1. Manual and automatic operation
2. Function annunciation

C. Prerequisites:

1. The applicable prerequisite checklist shall be checked off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer before the beginning of functional testing.

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

Function/Mode	Test Method
1. Verify installation of switch.	Manual

Function/Mode	Test Method
2. Demonstrate compliance with electrical sequence of operation.	Manual
3. Test for automatic transfer and retransfer upon loss of and subsequent de-energizing of utility power.	Manual
4. Check all indicating lights operable in proper mode of ATS operation.	Observation

E. Acceptance Criteria:

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

5.4 EMERGENCY LIGHTING TEST

A. Parties Responsible to Execute Functional Test:

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

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

1. Emergency Lighting Fixtures
2. Emergency Bypass Relays

C. Prerequisites:

1. The applicable prerequisite checklist shall be checked off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer before the beginning of functional testing.

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

Function/Mode	Test Method
1. Test system on generator power by de-energizing the normal utility power.	Manual
2. Test all manual controls individually.	Manual
3. Demonstrate all automatic functions using manual control overrides. Set all manual lighting controls in off (open) position to verify override of controls.	Manual
4. Demonstrate all interlocking functions, i.e., security/fire alarm.	Observation

E. Acceptance Criteria:

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

5.5 FIRE ALARM SYSTEM TEST

(This system will be tested by a third party, Cx scope limited to fire alarm interface with HVAC and ATC systems and coordination with third party test)

- A. Parties Responsible to Execute Functional Test:
 - 1. Vendor Support Representative
 - 2. Electrical Contractor
 - 3. Fire Protection Contractor: Assist in testing sequences.
 - 4. CxP: To witness and document testing.
 - 5. Owner's Representative: To observe.

- B. Integral Components or Related Equipment Being Tested: Pre-functional tests must be complete for all of the components listed below prior to performing this functional test.
 - 1. Complete fire alarm system
 - 2. Interconnection with fire protection equipment
 - 3. Interface with security system
 - 4. Interface with smoke sampling system

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

 - 2. First Party Testing Paperwork:
 - a. 1st party FA testing documentation to include Forms (see below for sample). These Forms are provided by the CxP and are intended to supplement the MIT Fire Alarm Acceptance 1st Party Testing Procedures document prepared by FA Contractor as well the testing and inspection requirements of NFPA 72 by providing project specific test Forms to be completed during 1st party tests.

 - b. These Forms allow testing to be documented at a greater level of detail beyond the standard forms provided by NFPA 72. These Forms do not replace the testing requirements of NFPA 72 and do not represent all aspects of a fire alarm acceptance test.

 - c. Sample Testing Forms:

<p>Test Date:</p> <p>Performed By:</p> <p>Phone:</p> <p>Email:</p> <p>Place a check mark next to EACH output that has been verified</p>	
SMOKE DETECTORS IN 1ST FLOOR ELEVATOR A LOBBY	
<u>SYSTEM OUTPUT</u>	
Confirm Smoke detector not within 3 feet of HVAC vent	
Confirm Smoke detector not within 4 inches of wall	
Activate Stair Pressurization system	
Activate Red Lens located on P1 outside of Elevator G	
Activate Red Lens located on P1 outside of Elevator A	
Actuate common audible and LED indicator for alarm signal at E38 FCC	
Actuate common audible and LED indicator for alarm signal at E37 FCC	
Display (LCD) and status change	
Illuminate smoke detector red LED by building & by floor at E38 FCC	
Illuminate smoke detector red LED by building & by floor at E37 FCC	
Illuminate the Alarm Audio Active red LED	
Transmit fire signal - AES Relay	
Transmit fire signal by building and illuminate corresponding DGP LED	
Broadcast the alert tone and pre-recorded emergency message in accordance with the evacuation matrix	
Broadcast the distinctive general evacuation signal (temporal 3) in accordance with the evacuation matrix, activate bed shaker	
Activate the visual notification appliances (strobes) in accordance with the evacuation matrix	
Actuate exterior beacon at fire department response point	
Release all magnetically held smoke doors to the areas receiving the evacuation signal	
Release all magnetically held smoke doors at the elevator lobbies on all floors of the building (E37 or E38W) in alarm	
Transmit fire alarm signal to access control system an unlock doors to the areas receiving the evacuation signal and the fire command center	
Shutdown associated air handling unit(s) and close associated fire/smoke dampers (see Note 1)	
Transmit alarm signal by device to the campus fire alarm reporting system via the DACT and RS-232 port	
Actuate Remote Indicator for inaccessible detectors	
Recall the elevator (alternate) to the second floor and activate the firemen's hat (steady)	
Release smoke guard on level P1 of elevator A lobby	
Actuate relay to the Garage system that elevator A is being recalled	

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

Function/Mode	Test Method
1. Test the entire fire alarm system in accordance with NFPA 72	Manual
2. Test flow switches by flowing water through an inspector's test connection. Adjust sensitivity per WFD requirements.	Both
3. Demonstrate tamper switches functions on all devices provided with tamper switches.	Manual
4. Demonstrate all functions of the voice evacuation systems in all areas equipped with voice evaluation signals.	Manual

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

1. Acceptance is achieved when all requirements of NFPA 72.B&20 met and test reports provided.

5.6 LIGHTING CONTROL SYSTEM TEST

A. Parties Responsible to Execute Functional Test:

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

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

1. Occupancy sensors

C. Prerequisites:

1. The applicable prerequisite checklist shall be checked off prior to functional testing. The commissioning agent may also spot-check misc. items and calibrations on the pre-functional checklists previously completed by the installer before the beginning of functional testing.

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

Function/Mode	Test Method
1. Demonstrate all functions of the occupancy/vacancy sensors.	Manual
2. Demonstrate all functions of the daylight harvesting sensors.	Manual
3. Demonstrate all functions of the automated shades (if applicable).	Manual
4. Verify proper lighting levels via foot-candle measurement in occupied areas.	Manual

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

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

6.0 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 each Section.
2. CxP Review:
 - a. Prior to substantial completion, the CxP shall review the O&M manuals, documentation to verify compliance with the Specifications. The CxP will communicate deficiencies in the manuals to the GC.
 - b. The GC and/or Subcontractors shall correct the deficiencies and resubmit to the CxP for review.
 - c. Upon a successful review of the corrections, the CxP recommends approval and acceptance of these sections of the O&M manuals to the GC and A/E.

7.0 TRAINING OF OWNER PERSONNEL

- A. The CxP shall be responsible for overseeing and coordination the training of Owner's personnel for commissioned equipment including the content and adequacy of the training. The CM shall be responsible for training execution and scheduling and ultimately for ensuring that training is completed.
- B. No later than 90 days in advance of Certificate of Occupancy, begin coordination of the training program for Owner's personnel.
- C. No later than 30 days in advance of the scheduled training, building tours shall be given to Owner's personnel. CM representative, knowledgeable with the systems, shall be available to accompany the tours. These tours will include the following systems at a minimum:
 - i. 2 tours for HVAC / Mechanical Technicians
 - ii. 2 tours for Electrical / Utilities Technicians
 - iii. 2 tours for Plumbing Technicians / Pipe Fitters
 - iv. 2 tours for Fire Protection Technicians
 - v. 2 tours for Building Control Instrument Technicians
- D. The training program set up will include the following steps:
 - i. The CxP shall interview the facility manager and MIT lead engineer to determine the special needs and areas where training will be most valuable. The Owner and CxP shall decide how rigorous the training should be for each piece of commissioned equipment. The CM shall communicate the results to the Subs and vendors who have training responsibilities.
 - ii. Create a preliminary training plan that includes scheduling, training agenda requirements and other pertinent information.

1. Each Sub and vendor responsible for training will submit a written training agenda to the CxP for review and approval prior to training. The agenda will cover the following elements (as applicable):
 - a. Equipment (included in training)
 - b. Intended audience
 - c. Location of training
 - d. Objectives
 - e. Subjects covered: (description, duration of discussion, special methods, etc.)
 - f. Duration of training on each subject
 - g. Index of handouts to be provided
 - h. Instructor for each subject
 - i. Methods (classroom lecture, video, site walk-through, actual operational demonstrations, etc.)
 - j. Instructor and qualifications
2. Each training session will consist of at least two sections:
3. Classroom session to include:
 - a. System overview discussions explaining the design intent, operating concepts and any unique features of the systems installed, including reviews of system one-line drawings.
 - b. Thorough review and discussion on the following Operational topics for each system/equipment/component:
 - i. Describe equipment operation within the entire system. Include startup, normal operation, emergency/alarm condition and shutdown, as well as the effects of these various modes of operation on the overall system.
 - ii. Describe equipment set up and why that particular set up was chosen. Also explain ramifications of changing the as-built set up.
 - iii. Describe equipment set points (with values) and why those set point values were chosen. Also explain ramifications of changing the as-built set points.
 - iv. Any special operating instructions and procedures.
 - c. Thorough review and discussion on the following Maintenance topics for each system/equipment/component:
 - i. Describe recommended maintenance/ preventative maintenance procedures.
 - ii. Review recommended maintenance/ preventative maintenance schedules.
 - iii. Explain common repair procedures.

1. Describe troubleshooting techniques and include instructions on meaning of warnings, trouble indications, and error messages.
 2. Recommended list of on-hand spare parts and part numbers.
 3. Instruction on use of special tools.
 - d. Document overview/review (I.e. O&Ms, as-built or record drawings, building one-line drawings, warranty information, maintenance service agreements, etc.)
4. Field session to include:
- a. Walk-Down of system and major equipment.
 - b. Procedures: Include the following:
 - i. Normal operating procedures such as startup, break-in, normal operating, safety, seasonal scheduling and shutdown.
 - ii. Special operating procedures such as emergency, failures of unique requirements for a given system or piece of equipment.
 - iii. Onboard control sequences.
 - c. Adjustments: Include the following:
 - i. Checking and making adjustments or alignments.
 - ii. Economy and efficiency adjustments.
 - d. Troubleshooting & Repair: Include the following:
 - i. Diagnostic instructions.
 - ii. Test and inspection procedures.
 - iii. Repair instructions.
 - iv. Disassembly; component removal, repair, and replacement; and reassembly instructions.
 - v. Instructions for identifying parts and components.
 - e. Maintenance: Include the following:
 - i. Inspection, routine maintenance and preventive maintenance procedures.
 - ii. Types of cleaning agents to be used and methods of cleaning.
 - iii. Instructions for testing each type of part.

- iii. Trainers must be well versed in the systems and equipment in which they are providing training, as well as be familiar with the installation and operation of those on this particular project. (Note: If factory representatives are used for equipment training, but they did not install the equipment, the session shall be supplemented by a representative of the installing Contractor.)
- iv. Each discipline shall receive a minimum of 4 training sessions. They shall be as follows:
 - 1. 2 sessions for 1st/3rd shift personnel (to start at 7:30am)
 - 2. 2 sessions for 2nd shift personnel (to start at 3:30pm)
- v. At least one session of each training topic shall be digitally recorded for Owner's use after the completion of the training program. These training videos shall be turned over with the O&M documents.
 - 1. Videos are to be provided for each equipment/system training session type.
 - 2. Video files that contain more than one training session (I.e. all HVAC related equipment and systems are in one file), the file is to be electronically indexed (tabbed) so each individual session can be found easily and immediately accessed.
 - 3. If multiple videos are taken during a single training session, the video files are to be combined into a single video file. Multiple files per equipment/system are not acceptable.
 - 4. Video files are to be named to accurately identify the training session and equipment/system for which instruction is being given.
- vi. The O&M Manuals and Systems Manuals are to be submitted and approved for use during training.
 - 1. For the primary HVAC equipment, the Controls Contractor shall provide a short discussion of the control of the equipment during the mechanical or electrical training conducted by others.
 - 2. The CxP develops an overall training plan and coordinates and schedules, with the CM and the Owner. The CxP develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc.
 - 3. The design engineer shall assist in training for the Owner. At the beginning of each discipline training session, the design engineer shall present an overall system design concept overview and shall include a review of all systems using the simplified system schematics (one-line drawings) including boiler water systems, AHU systems, heating systems, fuel gas supply systems, supply air systems, exhaust system and outside air strategies, dust collection and BAS system.

- vii. Training documentation shall include the following items:
 - 1. Copy of the training plan, including schedule, syllabus, and agenda
 - 2. Copy of the Owner's Program Requirements
 - 3. Copy of the Basis of Design
 - 4. Compiled Operations and Maintenance Manuals
 - 5. Red-lined drawings
 - 6. Training Sign-In sheets filled out by attendees
 - 7. Other relevant documents
 - viii. Any scheduling or scheduling changes shall be coordinated with the Owner to ensure availability of proper team members. A minimum 2 weeks' notice is required.
- E. In addition to these general requirements, the specific training requirements of Owner personnel by subs and vendors are specified in Divisions 1, 20, 21, 22, 23, 25 and 26.