COMMISSIONING SPECIFICATIONS

SECTION 019113 - GENERAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.1 CONDITIONS AND REQUIREMENTS

A. The General Conditions, Supplementary Conditions, and Division 1 – General Requirements apply.

1.2 SECTION INCLUDES

A. Commissioning of building systems, including but not limited to the following:

1. Mechanical Systems & Indoor Air Quality Systems

1.3 RELATED SECTIONS

A. Division 1 – Submittal Procedures
B. Division 22 – Commissioning of Plumbing
C. Division 23 – Commissioning of HVAC

1.4 DEFINITIONS

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

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

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

D. 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. Some reiterating of the design intent may be included.

E. Commissioning: A systematic process of ensuring that all building systems perform interactively according to the design intent and the owner's operational needs through the construction, acceptance and the warranty period with actual verification of performance. The commissioning process encompasses and coordinates the traditionally separate functions of system documentation, equipment startup, control system calibration, testing and balancing, performance testing and training. Commissioning during the construction phase is intended to achieve the following specific objectives in accordance with the Contract Documents:

1. Verify that applicable equipment and systems are installed in accordance with manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing contractor.
2. Verify and document proper performance of equipment and systems.
3. Verify that O&M documentation left on site is complete.
4. Verify that Owner's personnel are adequately trained.

The commissioning process does not take away from or reduce the responsibility of the system designers or installing contractor to provide a finished and fully functioning product.

F. Commissioning Agent (CA): The CA directs and coordinates the day-to-day commissioning activities. The CA does not take an oversight role like the CM. The CA shall report directly to the Owner.

G. Commissioning Plan: An overall plan, developed before or after bidding that provides the structure, schedule and coordination planning for the commissioning process.

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

I. Contractor: The general contractor or authorized representative.

J. Control System: The central building energy management control system.

K. Construction Manager (CM): The prime contractor for this project. Generally refers to all the Trades as well. Also referred to as the Contractor, in some contexts. The CM is hired by the owner to and is authorized to oversee the fulfillment of all requirements of the Contract Documents.

L. Datalogging: Monitoring flows, currents, status, pressures, etc. of equipment using stand-alone dataloggers separate from the control system.

M. Deferred Functional Tests: FPT's 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.

N. 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).

O. 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.

P. Design Narrative or Design Documentation: Sections of either the Design Intent or Basis of Design.

Q. Factory Testing: Testing of equipment at the factory with an Owner's representative present.

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

S. Indirect Indicators: Indicators of a response or condition, such as a reading from a control system screen reporting a damper to be 100 percent closed.

T. 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").

U. Monitoring: The recording of parameters (flow, current, status, pressure, etc.) of equipment operation using dataloggers or the trending capabilities of control systems.

V. Non-Compliance: See Deficiency.

W. Non-Conformance: See Deficiency.

X. 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 50 to 75 degrees F to verify economizer operation). See also "Simulated Signal."

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

Z. 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.

AA. Prefunctional Tests and Checklists (PFT's): A list of items to inspect and elementary component tests to conduct to verify proper installation of equipment, provided by the CA to the Contractor. Prefunctional checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels OK, labels affixed, gages in place, sensors calibrated, etc.). However, some prefunctional checklist items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a three phase pump motor of a chiller system). The word

prefunctional refers to before functional testing. Prefunctional checklists augment and are combined with the manufacturer's start-up checklist. Even without a commissioning process, the contractor typically perform some, if not many, of the prefunctional checklist items a commissioning authority will recommend. However, few contractors document in writing the execution of these checklist items. Therefore, for most equipment, the contractor executes the checklists on their own. The CA only requires that the procedures be documented in writing, and does witness much of the prefunctional checklisting only items listed to be tested by sampling will not be witnessed fully.

BB. Project Manager (PM): The individual employed by the Owner to be responsible for the overall management and oversight of the Project.

CC. Sampling: Functionally testing only a fraction of the total number of identical or near identical pieces of equipment.

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

EE. 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).

FF. 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.

GG. Startup: The initial starting or activating of dynamic equipment, including executing prefunctional checklists.

HH. Trades: The contractor who provides and installs building components and systems.

II. Test Procedures: The step-by-step process that must be executed to fulfill the test requirements. The test procedures are developed by the CA.

JJ. Test Requirements: Requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures.

KK. Trending: Monitoring using the building control system.

LL. Vendor: Supplier of equipment.

MM. Warranty Period: Warranty period for entire project, including equipment components. Warranty begins at Substantial Completion and extends for a period indicated in the Contract Documents and accepted submittals.

1.5 ABBREVIATIONS

A. Abbreviations: The following are common abbreviations used in the Project Manual and in the Commissioning Plan.

A/E - Architect and design Engineers
CA - Commissioning Agent
CC - Controls Trade
CM/PC - Construction Manager or Prime Contractor
Cx - Commissioning
Cx Plan - Commissioning Plan document
EC - Electrical Trade
FPT - Functional performance test
MC - Mechanical Trade
PFT - Prefunctional tests and checklists
PM - Project Manager (of the Owner)
Trades - The contractor or various trades
TAB - Test, Adjusting & Balancing Trade

1.6 COORDINATION

A. Commissioning Team: The members of the commissioning team consist of the following:
1. Owner's Project Manager (PM);
2. Commissioning Agent (CA);
3. Designee of the Owner's Construction Management firm (CM);
4. Architect and/or design engineers (particularly the mechanical engineer);
5. Mechanical Trades (MC);
6. Electrical Trades (EC);
7. Representative of TAB Trades (TAB);
8. Controls Trades (CC);
9. Any other installers or suppliers of equipment;
10. The building or plant operator/engineer.

B. Management: The CA is hired by the Owner. The CA directs and coordinates the commissioning activities and reports to the Owner and CM. All members work together to fulfill their respective contracted responsibilities and to meet the objectives of the Contract Documents.

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

1. The CA will provide the initial schedule of primary commissioning events at the commissioning coordination meeting. The "Commissioning Plan" provides a format for this schedule. As construction progresses more detailed schedules are developed by the CA in coordination with the Commissioning Team.

1.7 COMMISSIONING PROCESS

A. Commissioning Plan: The "Commissioning Plan," is binding on the Contractor. The "Commissioning Plan" provides guidance in the execution of the commissioning process. After the initial commissioning coordination meeting the CA will update the plan, which will continue to evolve as the project progresses.

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

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

1.8 SUBMITTALS

A. Submit under provisions of Div 1.

B. The CA will provide the contractor with a specific request for the type of submittal documentation the CA requires to facilitate the commissioning work. These requests will be integrated into the normal submittal process and protocol of the construction team. At minimum, the request will include the manufacturer and model number, the manufacturer's printed installation and detailed start-up procedures, full sequences of operation, O&M data, performance data, any performance test procedures, control drawings and details of owner

contracted tests. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning authority. All documentation requested by the CA will be included by the Trades in their O&M manual contributions.

C. The CA will review and approve submittals related to the commissioned equipment for conformance to the Contract Documents 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 and only secondarily to verify compliance with equipment specifications. The CA will notify the CM, PM or A/E as requested, of items missing or areas that are not in conformance with Contract Documents and which requires resubmission.

D. The CA may request additional design narrative from the A/E and CC, depending on the completeness of the design intent documentation and sequences provided with the Specifications.

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

1.9 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 Division 1. Special requirements for the CC and TAB are found in Div 23.
2. CA Review and Approval: Prior to substantial completion, the CA shall review the O&M manuals, documentation and redline as-builts for commissioned systems to verify compliance with the Specifications. The CA will communicate deficiencies in the manuals to the CM, PM or A/E, as requested. Upon a successful review of the corrections, the CA recommends approval and acceptance of these sections of the O&M manuals to the CM, PM or A/E. The CA also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated. This work does not supersede the A/E's review of the O&M manuals according to the A/E's contract.

1.10 COMMISSIONING RECORD

A. Documentation of Commissioning Process:

1. The CA is responsible to compile, and organize the following commissioning data, by system, into indexed three-ring binders for delivery to the Owner. The Commissioning Record shall include 5 main sections:
    a. Commissioning Plan
    b. Final Commissioning Report
    c. Systems and Energy Management Manual
    d. Commissioning Testing Record

e. Training Record

f. Issues and Deficiencies Record

2. The Final Commissioning Report shall include:

a. Executive summary

b. List of participants and roles

c. Brief building description

d. Overview of commissioning and testing scope

e. General description of testing and verification methods.

f. Assessment of the adequacy of each system in the following areas:

1) Meeting the equipment specifications

2) Installation in accordance with design documents

3) Functional performance and efficiency

4) Meeting design intent

5) Documentation and O&M manual content

6) Conduct of operator training

3. The Commissioning Testing Record shall include:

a. Completed Prefunctional checklists and system startup forms

b. Completed functional performance testing forms for each system

4. The Training Record shall include:

a. Overall Training Plan

b. Written training plans

c. Attendance records

d. Video training record (if required).

5. The Issues and Deficiencies Record shall include:

a. Open Items Listing

b. Closed Items Listing

1.11 COMMISSIONING RESPONSIBILITIES

A. The responsibilities of various parties in the commissioning process are provided in this section. The responsibilities of the mechanical Trade, TAB Controls Trade are in Division 23 commissioning specifications. The responsibilities of the Electrical Trade are in Division 26 commissioning specifications. The services of the Project Manager, Construction Manager, Architect, HVAC mechanical and electrical designers/engineers, and Commissioning Agent are not provided for in this contract. That is, the Contractor is not responsible for providing their services. Their responsibilities are listed here to clarify the commissioning process.

B. All Parties:

1. Follow the Commissioning Plan.

2. Attend the commissioning coordination meeting and additional meetings, as necessary.

C. Architect (or A/E):

1. Construction and Acceptance Phase:
   a. The CM coordinates with the CA contract for the Owner.
   b. Attend the commissioning coordination meeting and selected commissioning team meetings.
   c. Perform normal submittal review, construction observation, record drawing preparation, O&M manual preparation, etc., as contracted.
   d. Provide any design narrative documentation requested by the CA.
   e. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
   f. Provide design intent (BOD) and owners project requirement (OPR)

2. Warranty Period:
   a. Coordinate resolution of design non-conformance and design deficiencies identified during warranty-period commissioning.

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

1. Construction and Acceptance Phase:
   a. Perform normal submittal review, construction observation, record drawing preparation, etc., as contracted. One (1) site observation should be completed just prior to system startup.
   b. Provide any design narrative and sequences documentation requested by the CA. The designers shall assist (along with the contractors) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
   c. Attend commissioning coordination meetings and other selected commissioning team meetings.
   d. Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
   e. Review and approve the O&M manuals.
   f. From the Contractor's red-line drawings, edit and update one-line diagrams developed as part of the design narrative documentation and those provided by the vendor as shop drawings for the commissioned systems.
   g. Provide system overviews at the training sessions for the Owner's personnel.

2. Warranty Period:

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

E. Commissioning Agent (CA):

1. The CA is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management.

The CA may assist with problem solving, non-conformance issues or deficiencies, but ultimately that responsibility resides with the CM and the A/E. The primary role of the CA is to develop and coordinate the execution of a testing plan, observe and document performance to verify that systems are functioning in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, check out and functionally test equipment and systems.

2. Construction and Acceptance Phase:

   a. Coordinate and direct the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consult with all necessary parties, frequently updated timelines and schedules and provide technical expertise.

   b. Coordinate the commissioning work and, with the CM, ensure that commissioning activities are being scheduled into the master schedule.

   c. Update the Commissioning Plan as the project progresses

   d. Plan and conduct a commissioning coordination meeting and other commissioning meetings.

   e. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.

   f. Before startup, gather and review the current control sequences and interlocks and work with contractor and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.

   g. Concurrent with the A/E reviews, review Contractor submittals for systems being commissioned for compliance with commissioning needs.

   h. Review and, where necessary, write and distribute prefunctional tests and checklists.

   i. Perform site visits, as necessary, to observe component and system installations.

   j. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.

   k. Witness selected parts of the piping tests and flushing procedures, sufficient to be confident that proper procedures are being followed. The contractor shall provide a minimum of two days notice to CA as to when testing shall be completed. Include Contractor’s documentation of this testing and include the commissioning record.

   l. Witness selected parts of the ductwork testing and cleaning procedures, sufficient to be confident that proper procedures are being followed. The contractor shall provide a minimum of two days notice to CA as to when testing shall be completed. Include Contractor’s documentation of this testing and include the commissioning record.

   m. Obtain Contractor Signature, fill in Prefunctional startup checklists, review and approve completed Prefunctional test and startup reports.

   n. Review TAB execution plan and readiness of CC to assist in the process.

o. Review completed air and water balancing reports and verify by spot testing, and selected site observation.

p. Write the functional performance test procedures for equipment and systems with assistance from installing contractors.

q. Coordinate, witness and approve functional performance tests. Coordinate retesting as necessary until satisfactory performance is achieved.

r. Analyze sufficient functional performance trend logs and monitoring data to verify performance.

s. Maintain a master issues and deficiencies log separate from the testing record.

t. Provide the CM and Owner with written progress reports noting substantive issues with recommended actions.

u. Oversee and approve (but do not conduct) the training of the Owner's operating personnel.

v. Review and approve the O&M manuals.

w. Provide a final commissioning report (as described in this section).

3. Warranty Period:

a. Coordinate and supervise required seasonal or deferred testing and deficiency corrections.

b. Return to the site at 2 months prior to the end of the warranty period and review the commissioned systems and any outstanding issues with CM, contractors and the facilities staff. Identify issues requiring resolution prior to end of warranty.

F. Construction Manager (CM):

1. Construction and Acceptance Phase:

a. Include the cost of commissioning (CM's and Trade content) in the total contract price.

b. In each purchase order or subcontract written, include requirements for submittal data, O&M data, commissioning tasks and training.

c. Furnish in a timely manner a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned systems and equipment to the CA.

d. Ensure that all Trades execute their commissioning responsibilities according to the Contract Documents and schedule.

e. Facilitate the coordination of the commissioning work by the CA, and, with the CA, ensure that commissioning activities are being scheduled into the master schedule.

f. Attend a commissioning coordination meeting and other commissioning team meetings.

g. Perform the normal review of submittals.

h. Review the functional performance test procedures submitted by the CA, prior to testing.

i. When necessary, observe and witness prefunctional checkout, startup and functional testing of selected equipment.

j. Review commissioning progress and deficiency reports.

k. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.

l. Coordinate the training of owner personnel.

m. Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.

2. Warranty Period:

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

b. Ensure that Trades execute seasonal or deferred functional performance testing, witnessed by the CA, according to the specifications.

c. Ensure that Trades correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

G. Owner's Project Manager (PM):

1. Construction and Acceptance Phase:

a. Manage the contract of the A/E and of the CM.

b. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training sessions.

2. Warranty Period:

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

H. Trade Contractors (Division 23 and 26):

1. Construction and Acceptance Phase:

a. Include and itemize cost of commissioning in contract price.

b. Include requirements for submittal data, commissioning documentation, O&M data and training in each subcontract written.

c. Attend commissioning scoping meeting and other meetings necessary to facilitate commissioning process.

d. Provide CA with normal cut sheets and shop drawing submittals of commissioned equipment.

e. Provide additional requested documentation to CA for development of start-up and functional testing procedures. This data request may be made prior to normal submittals.

f. Assist in clarifying operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.

g. Provide assistance to the CA in preparing the specific functional performance test procedures. Review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.

h. Develop full start-up and initial checkout plan using manufacturer's start-up procedures and prefunctional checklists from CA for commissioned equipment. Submit to CA for review and approval prior to startup.

i. Perform and document prefunctional checks, startup, and initial checkout for commissioned equipment. Provide a copy of all checklists and startup forms to the CA.

j. Address punch list items before functional testing.

k. Verify that air and water TAB is complete with discrepancies and problems remedied before performing functional testing of respective systems.

l. Provide skilled technicians to execute starting of equipment and functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving.

m. Correct issues and deficiencies and retest equipment.

n. Prepare O&M manuals in accordance with Division 23, including clarifying and updating original sequences of operation to as-built conditions.

o. During construction, maintain as-built drawings. Update and submit after completion of commissioning.

p. Provide training of Owner's operating staff using qualified personnel familiar with the project.

q. Coordinate with equipment manufacturers to determine specific requirements to maintain warranty.

2. Warranty Period:

a. Execute seasonal or deferred functional performance testing, witnessed by CA in accordance with the specifications.

b. Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal testing.

1.12 SYSTEMS TO BE COMMISSIONED

A. The following systems will be commissioned on this project:

1. Mechanical Systems
   a. Chillers
   b. Primary Chilled Water Pumps
   c. Refrigerant Monitoring System
   d. Condensing Hot Water Boilers
   e. Primary Hot Water Pumps
   f. Cooling Towers (Fans, Valves)
   g. Condenser Water Pumps
   h. Dual Temperature Secondary Pumps

i. Piping and Valves
j. Piping Insulation
k. Building Management System

2. Plumbing Systems
   a. Domestic Hot Water System

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

A. All testing equipment required to perform startup, initial checkout, and functional performance testing shall be provided by the Division Contractor.

B. Two-way radios shall be provided by the Division Contractor during functional testing activities.

C. Include special tools and instruments required for testing, according to the Contract Documents. Refer to Trade Divisions for details.

D. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the Project Specifications.

PART 3 - EXECUTION

3.1 MEETINGS

A. Commissioning Kick-Off Meeting: Within 90 days of commencement of construction, the CA will schedule, plan and conduct a commissioning coordination meeting with the entire commissioning team in attendance. Meeting minutes and updated test plans will be distributed to all parties by the CA.

B. Routine Commissioning Meetings: Periodic meetings will be planned and conducted by the CA as construction progresses. These meetings will cover coordination, deficiency resolution and planning issues with particular Trades. The CA will plan these meetings to minimize time spent by Trades. These meetings will increase in frequency as the project draw closer to completion.

3.2 REPORTING

A. The CA will provide regular reports to the Owner and CM, with increasing frequency as construction and commissioning progresses.

B. The CA will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress, issues and deficiencies, and scheduling changes through memos, progress reports, etc.

C. The CA will provide a Final Commissioning Report to the Owner and CM as described in Section 1.10, Commissioning Record.

3.3 PREFUNCTIONAL CHECKLISTS AND START-UP

A. The following procedures apply to all systems and equipment to be commissioned.

B. General: Prefunctional tests and checklists (PFT's) are important to ensure that the equipment and systems are connected properly and are operational. PFT's ensure that functional performance testing may proceed without unnecessary delays. The Contractor shall be responsible for performing Prefunctional testing. EVERY piece of equipment receives a full Prefunctional checkout.

C. The primary role of the CA in this process is to ensure that there is written documentation and that each of the manufacturer-recommended procedures have been completed.

1. The CA prepares prefunctional checklists for typical MEP systems. These checklists are provided to the CM for distribution to the responsible trade(s). Each form may have more than one trade responsible for its execution.
2. The Trade responsible for the purchase of the equipment develops a full start-up plan by combining the CA's checklists with the manufacturer's detailed start-up and checkout procedures.

D. Execution of Prefunctional Checklists and Startup:

1. Trade schedule startup and checkout with the CM and CA.
2. The Trades and vendors shall execute startup in the presence of the CA and provide the CA with a signed and dated copy of the completed start-up and prefunctional tests and checklists. Only individuals that have direct knowledge and have witnessed that a line item task on the Prefunctional checklist was actually performed shall initial or check off that item.
3. The CA will observe selected Prefunctional tests and startup procedures.
4. The CA will review ALL Prefunctional test forms furnished by the Trades and compile in Commissioning Record.

E. Issues and Deficiency Resolution:

1. The Trades shall clearly list any issues and deficiencies identified in the initial start-up and PFT procedures and return the completed test form to the CA within two days.
2. Problem Solving: The CA shall work with the CM and Trades to correct issues or deficiencies. The CA will involve the CM, the A/E and others as necessary. The CA may recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the CM, Trades and A/E.
3. The installers shall correct all areas that are deficient in a timely manner and notify the CA as soon as outstanding items have been corrected. An updated PFT form shall be submitted to CA when complete.
4. Upon completion of all associated PFT's, the system will then be scheduled for functional performance testing by the Commissioning Team.

3.4 FUNCTIONAL PERFORMANCE TESTING

A. This article applies to all commissioning functional testing for all divisions.

B. A detailed list of systems to be commissioned is referenced in Section 1.12, “SYSTEMS TO BE COMMISSIONED”. The specific equipment to be tested is found in the applicable commissioning sections of Divisions 23 and 26.

C. The appropriate parties responsible to execute each portion of the functional test shall be coordinated by the CA.

D. Objectives and Scope: The objective of functional performance testing is to demonstrate that each system is operating according to the design intent and Contract Documents.

E. In general, each system will be tested in all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load, etc.).

F. Development of Test Procedures:

1. The Trades provide CM and CA with documents describing final approved equipment, configuration and control sequences.
2. The CA develops specific test procedures and forms to verify and document proper operation of each system.
3. Prior to execution, the CA shall provide a copy of the test procedures to the Contractor who shall review the tests for feasibility, safety, equipment and warranty protection.
4. The CM will provide the CA with copies of owner-contracted, factory testing or acceptance tests that the CA is not responsible to oversee. The CA shall include these tests in the Commissioning Record.

G. Sample Forms:

1. The test procedure forms developed by the CA 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. Unique test ID number, and reference to unique prefunctional checklist and start-up documentation ID numbers for the piece of equipment
    d. Date
    e. Project name
    f. Participating parties
    g. A copy of the specification section describing the test requirements
    h. A copy of the specific sequence of operations or other specified parameters being verified
    i. Formulas used in any calculations
    j. Required pre-test field measurements

k. Instructions for setting up the test.

l. Special cautions, alarm limits, etc.

m. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format.

n. 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.

o. A section for comments

p. Signatures and date block for the CA

H. Test Methods:

1. Functional performance testing and will generally be achieved by manipulating the control systems or equipment and observing system response. Means by which manipulation may occur include:
   a. Simulated Conditions
   b. Overwritten Values
   c. Simulated Signals
   d. Altering Setpoints
2. Setup: Each test shall be performed under conditions that simulate actual conditions as close as practically possible.
3. Trend logging or data loggers may be used to confirm short or long term system response and performance.
4. At completion of a test, the Trade shall return all affected building equipment and systems to their pre-test conditions.
5. Sampling: Multiple identical pieces of non-life-safety or non-critical equipment may be functionally tested using a sampling strategy. Systems to be tested by sampling methods, if any, are identified in Section 1.12 “SYSTEMS TO BE COMMISSIONED”. If sampling strategy is applied, the CA shall define systems appropriate for sampling and specify sampling population. Note: No sampling will be allowed in prefunctional checklist execution.
   a. The following strategy (“xx% Sampling—yy% Failure Rule”) shall be utilized when functional performance testing is applied to a sample of the project systems:

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

      yy = the percent of the sample that if failing, will require another sample to be tested.
   b. The example below describes a 20% Sampling—10% Failure Rule.
      1) Randomly test at least 20 percent (xx) of each group of identical equipment. In no case test less than three units in each group. This 20 percent, or three, constitute the “first sample.”
      2) If 10 percent (yy) of the units in the first sample fail the functional performance tests, test another 20 percent of the group (the second sample).
      3) If 10 percent of the units in the second sample fail, test all remaining units in the whole group.

4) If at any point, frequent failures are occurring and testing is becoming more troubleshooting than verification, the CA may stop the testing and require the responsible Trade to perform and document a checkout of the remaining units, prior to continuing with functionally testing the remaining units.

I. Coordination and Scheduling:

1. The contractor shall provide sufficient notice to the CA regarding their completion schedule for the prefunctional checklists and startup of all equipment and systems. The CA will schedule functional tests through the CM and related Trades. The CA shall direct, witness and document the functional testing of all equipment and systems. The Trades shall execute the tests.
2. Functional testing is conducted after prefunctional testing and startup has been satisfactorily completed. The control system is sufficiently tested and approved by the CA before it is used for TAB or to verify performance of other components or systems. The air balancing and water balancing is completed and debugged before functional testing of air-related or water-related equipment or systems. Testing proceeds from components to subsystems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is checked.

J. Test Equipment: Refer to Section 2.1, “TEST EQUIPMENT”, for test equipment requirements.

K. Issues and Deficiency Resolution: (See Section 3.5, “ISSUES, DEFICIENCIES AND COST OF RETESTING”

3.5 ISSUES, DEFICIENCIES AND COST OF RETESTING

A. Issues and Deficiencies:

1. All issues and deficiencies shall be noted in the Issues and Deficiencies Log by the CA.
2. The CA shall work with the CM and Trades to correct issues or deficiencies identified during functional testing. The CA will involve the CM, the A/E and others as necessary. The CA may recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the CM, Trades and A/E.
3. Corrections of minor deficiencies identified may be made during the tests at the discretion of the CA. In such cases the deficiency and resolution will be documented on the procedure form.
4. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the CA will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so at the request of the CM or Owner.
5. As tests progress and a deficiency is identified, the CA discusses the issue with the contractor.
    a. When there is no dispute on the deficiency and the Trade accepts responsibility to correct it and notifies the CA of completion.

1) The CA reschedules the test and the test is repeated.

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

1) Once the interpretation and resolution have been decided, in cooperation with the CM, the appropriate party corrects the deficiency and notifies the CA of completion.

2) The CA reschedules the test and the test is repeated.

6. The CA retains the original Issues and Deficiencies Log until the end of the project.

B. Cost of Retesting:

1. The cost for the Trade to retest a prefunctional or functional test, if they are responsible for the deficiency, shall be theirs. If they are not responsible, any cost recovery for retesting shall be negotiated with the CM.
2. For a deficiency not related to any prefunctional checklist or start-up fault, the following shall apply: The CA and CM will direct the retesting of the equipment once at no "charge" for their time. However, the CA's time for a second retest will be charged to the CM.
3. The time for the CA and CM to direct any retesting on systems or equipment reported to have been successfully completed, but determined during functional testing to be faulty, will be back charged by the CM to the trade responsible for necessitating the retesting.
4. Refer to the sampling article of this section for requirements for testing and retesting identical equipment.
5. Any required retesting shall not be considered a justified reason for a claim of delay or for a time extension by the Contractor or any trade.

3.6 TRAINING OF OWNER'S PERSONNEL

A. Training – General Responsibilities

1. The CM and the trades shall be responsible for training coordination, scheduling, and ultimately for ensuring that training is completed.
2. The CM shall be responsible for recording attendance at each training session.
3. The CA develops an overall training plan and coordinates this with the CM. The CA develops criteria for determining that the training was satisfactorily completed.

B. Training Planning

1. The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment.
   a. The CA shall interview the facility manager and lead engineer to determine the special needs and areas where training will be most valuable. The Owner and CA shall decide how rigorous the training should be for each piece of commissioned equipment. The CA shall communicate the results to the contractor and trades who have training responsibilities.
   b. Major training topics and minimum contractor/vendor training time requirements are specified in Division 23 and 26.

c. Each Trade is responsible for training will submit a written training plan to the CA 2 months prior to planned training for review and approval. The plan will cover the following:
   1) Equipment included in training
   2) Intended audience
   3) Location of training
   4) Objectives
   5) Subjects covered (description, duration of discussion, special methods, etc.)
   6) Duration of training on each subject
   7) Instructor for each subject
   8) Methods (classroom lecture, video, site walk-through, actual operational demonstrations, written handouts, etc.)
   9) Instructor and qualifications

d. For the primary HVAC equipment, the Controls trade shall provide a short discussion of the control of the equipment during the mechanical or electrical training conducted by others.

C. Training Execution

1. Training shall occur after functional testing is complete, unless approved otherwise by Owner's representative.
2. Training shall normally start with classroom sessions followed by hands-on sessions for each piece of equipment. Various modes of operation shall be demonstrated.
3. Training shall include:
   a. Use of printed installation, operation and maintenance instruction material included in O&M manuals.
   b. Review of written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. Training shall include start-up, operation in modes possible, shutdown, seasonal changeover and any emergency procedures.
   c. Discussion of relevant health and safety issues and concerns.
   d. Discussion of warranties and guarantees.
   e. Common troubleshooting problems and solutions.
   f. Explanatory information included in O&M manuals and location of plans and manuals in the facility.
   g. Discussion of any peculiarities of equipment installation or operation.
   h. Classroom sessions shall include use of overhead projections, slides, video and audio taped material as might be appropriate.
4. Hands-on training shall include start-up, operation in all modes possible, including manual, shutdown and any emergency procedures and preventative maintenance for all pieces of equipment.

3.7 DEFERRED AND SEASONAL TESTING

A. Seasonal Testing: During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) shall be completed as part of this contract. The CM shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the appropriate Trades, with facilities staff and the CA witnessing. Any final adjustments to the O&M manuals and as-built documentation will be made.

B. Unforeseen Deferred Tests: If any check or test cannot be completed due to building readiness, required occupancy, or specific deficiency, functional testing may be delayed upon approval of the PM. These tests will be conducted in the same manner as the seasonal tests.

3.8 WRITTEN WORK PRODUCTS

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

	Product	**Developed By**
1.	Final commissioning plan	CA
2.	Meeting minutes	CA
3.	Commissioning schedules	CA with CM
4.	Equipment submittals	Contractor
5.	Sequence clarifications	Contractor and A/E as needed
6.	Prefunctional checklist forms	CA with assistance of Trades
7.	Prefunctional checklist and contractor/vendor startup forms (filled out)	Trades in presence of CA
8.	Preliminary and Final TAB reports	TAB
9.	Issues and Deficiencies Log	CA
10.	Commissioning Progress Reports	CA
11.	Functional Performance Test forms	CA
12.	Functional Performance Test forms (filled out)	CA with assistance of Trades
13.	O&M manuals	Contractor
14.	Commissioning Record	CA
15.	Overall training plan	CA and CM with assistance of Trades
16.	Specific training agendas	Trades with assistance of vendors
17.	Final Commissioning Report	CA

PART 4 – SAMPLE PREFUNCTIONAL CHECKLISTS

A. The following pages are not project specific however these checklists are meant to give an example of the rigor test that is expected for checklists, tests, etc.

Client – Project Name

Air Handling Unit

PRE-FUNCTIONAL SYSTEM CHECKLIST

Mechanical Contractor	**Date**	**Controls Contractor**	**Date**
Electrical Contractor	**Date**	**Sheet Metal Contractor**	**Date**
Contractor	**Date**	**General Contractor**	**Date**

PROJECT:	***Project Name***	**SYSTEM I.D.#**	
LOCATION:	***City, NY***	**EQUIPMENT I.D.#**	**AHU**

B. ITEM	OK	COMMENT
AHU		
6” housekeeping pad installed		
Check mountings (shipping bolts removed)		
Verify equipment guards installed		
Pulleys aligned and belt tension correct		
Plenums clear and free of loose material		
Fan rotates freely		
Fan motor and linkages lubricated		
Fire and balance dampers free to operate		
Motorized dampers move freely and stroke when commanded		
Temporary start-up construction filters installed.		
Electrical connections complete		
Disconnect switch installed		
VFD installed and started		
Fan room clean for start-up		
Hot water coil clean and clear-piping complete		
Cooling coil clean and piping complete		
Condensate drains clear and piped		
Humidifier section installation completed		

PROJECT: *Project Name*	SYSTEM I.D.#	
LOCATION: *City, NY*	EQUIPMENT I.D.#	AHU

B. ITEM	OK	COMMENT
Safety controls operational		
Ductwork clean and sealed		
ATC controls complete (point to point checkout)		
Bump fan to check rotation (VFD and by-pass)		
CHILLED WATER COIL EQUIPMENT		
Shut off valves supply and return installed.		
Strainer installed.		
(2) Way modulating control valve installed.		
Thermometers -supply and return installed.		
Flushing connection / air vent installed.		
Drain valve installed.		
Balancing valve installed.		
Flow measurement device installed		
Condensate drain pan trapped and piped.		
HOT WATER PREHEAT COIL		
Supply shut off valve installed.		
Strainer installed.		
Flow measurement device installed		
Thermometers - supply and return installed.		
Automatic air vent installed.		
Drain valve installed.		
Balancing valve installed.		
Flow measurement device installed		
(2) Way modulating control valve installed.		
Return shut off valve with memory stop installed.		
HUMIDIFIER BANK EQUIPMENT		
Shut off valve installed.		
Strainer installed.		
Steam trap assembly installed		
Steam modulating control valve installed.		
Steam trap assembly installed		
Condensate bypass with shut-off installed		
Min 6” dirt leg installed		
Gate valve shut off installed.		
Aftercooler with cooling water piped to drain		

PROJECT:	***Project Name***	**SYSTEM I.D.#**	
LOCATION:	***City, NY***	**EQUIPMENT I.D.#**	**AHU**

B. ITEM	**OK**	**COMMENT**
Check vertically mounted disperson tube is clean.		
Casing penetrations are sealed and will not leak		
Drain pan trapped and piped		

COMMENTS:			
PRE-START BY:		**DATE:**	
START-UP BY:		**DATE:**	

Client – Project Name

Air Handling Unit

FUNCTIONAL PERFORMANCE TEST – RECORD SHEET

A. Documentation Requirements

Prior to the functional performance test and verification process, the Commissioning Agent requires the following documentation:

1. Air and Water Balancing Report
2. Operations and Maintenance Data
3. Verification of Warranty Periods on Equipment
4. Verify Owner Training is Complete

PRODUCT DATA SHEET 1 - B. System Components

Prior to the functional performance and verification process, the Commissioning Agent shall verify all major system components, capacities, configurations and support functions are consistent with the design or documentation received. The following shall be verified:

1. AHU Identification _____
   Supply Fan Identification _____
   Return Fan Identification _____

2. Supply Fan Motor Performance:
   Return Fan Motor Performance:

HP	RPM	Voltage	Phase	FLA

3. Verify factory start-up has been performed and reports submitted:
   - AHU per specification section XXXX-XX.
   - VFD's per specification section XXXX-XX.

   Compliance: _____
   Non-compliance: _____

   Remarks:

4. Verify duct insulation is applied in accordance with specification section XXXXX:
   - Air conditioning ducts in concealed locations are to be insulated with XX" rigid or flexible fiberglass.
   - Air conditioning ducts in exposed locations and mechanical rooms are to be insulated with XX" rigid fiberglass

   Compliance: _____
   Non-compliance: _____

   Remarks:

5. Verify installation of duct lagging (acoustic insulation) where required per the contract documents:
   - Verify that duct lagging has been installed per detail X on drawing XXXX.

   Compliance: _____
   Non-compliance: _____

   Remarks:

6. Verify fan rotation, lubrication and belt alignment for both supply fans and the return fan.

   Compliance: _____
   Non-compliance: _____

   Remarks:

7. Verify construction start-up filters were removed and replaced with new filters:
   - Pre-filters (30% pleated)
   - Final Filters (60% pleated)
   - HEPA Filters (90% cartridge)

   Compliance: _____
   Non-compliance: _____

   Remarks:

8. Verify unit is installed with ample clearance for maintenance and repair of all components.
   - Verify supply and return fan access and coil pull space.

   Compliance: _____
   Non-compliance: _____

   Remarks:

9. Verify fans have been statically and dynamically balanced:
   - Observe operation for evidence of extensive vibration or noise.

   Compliance: _____
   Non-compliance: _____

   Remarks:

10. Verify motor efficiency complies with specification section XXXXX.

    Compliance: _____
    Non-compliance: _____

    Remarks:

11. Verify unit installation:

	Yes		***No***
Return Fan Section			
Belt Guard	N/A		
Fan Spring Isolators	N/A		
Extended Lube Lines	N/A		
Economizer/Mixing Section			

Outdoor Air Damper w/ Actuator	X		
Mixed Air Damper w/ Actuator	X		
Exhaust Air Damper	X		
Pre-Filter Section			
2” Pleated Pre-Filter Section	X		
Filter Rack Blank-off Plates	X		
Filter Section			
4” (65%) Pleated Pre-Filter Section	X		
Filter Rack Blank-off Plates	X		
Heating Coil Section			
Hot Water Heating Coil	X		
Stainless Steel Drain Pan	X		
Cooling Coil Section			
Chilled Water Cooling Coil	X		
Stainless Steel Condensate Drain Pan	X		
Condensate Drain Line and Trap	X		
Supply Fan Section			
Belt Guard	N/A		
Fan Spring Isolators	N/A		
Extended Lube Lines	N/A		
Discharge Plenum			

Re-
marks:

12. Verify installation of convenience outlet, sectional marine lights and single point power connection with non-fused disconnect per schedule notes on drawing XXXX.

    Compliance: _____
    Non-compliance: _____

    Remarks:

13. Verify installation of maganhelic filter differential pressure gauge per specification section XXXXX.
    - Record gauge range and compare with specification section XXXXX.
    - Verify gauges installed across each filter bank.

    Compliance: _____
    Non-compliance: _____

    Remarks:

14. Verify installation of supply and return smoke/isolation dampers as required per the contract documents.
    - Verify that access doors have been installed for visual inspection per specification section XXXX.

    Compliance: _____
    Non-compliance: _____

    Remarks:

15. Verify installation of fire dampers as required per the contract documents.
    - Verify that access doors have been installed for visual inspection per specification section XXXX.

Compliance: _____
Non-compliance: _____

Remarks:

16. Verify chilled water coil piping arrangement per detail X on drawing XXXX:

	Yes		***No***
CHWS Isolation Valve			
CHWS Strainer w/ Blowdown Valve			
CHWS 2-Way Control Valve			
CHWS Thermometer			
CHWS Automatic Air Vent w/ Petcock			
CHWS Hose End Drain Valve			
CHWR Balancing Valve			
CHWR Thermometer			
CHWR Automatic Air Vent w/ Petcock			
CHWR Hose End Drain Valve			
Coil Automatic Air Vent w/ Petcock			
Coil Hose End Drain Valve			
Piping Insulation Complete			
Piping Identification Installed			
Valve Tagging Complete			

Remarks:

17. Verify installation of CHWS/CHWR manifold pressure gauge with petcocks per detail X on drawing XXXX.
    - Record gauge range and compare with specification section XXXX.

Compliance: _____
Non-compliance: _____

Remarks:

18. Verify installation of stainless steel CHW coil condensate drain pan.
    - Verify drain pan is pitched towards drain connections.

Compliance: _____
Non-compliance: _____

Remarks:

19. Verify installation of cooling condensate drain line and trap per detail X on drawing XXXX.

Compliance: _____
Non-compliance: _____

Remarks:

20. Verify hot water coil piping arrangement per detail 11 on drawing M402:

	Yes		***No***
HWS Isolation Valve			
HWS Strainer w/ Blowdown Valve			
HWS 2-Way Control Valve			
HWS Thermometer			
HWS Automatic Air Vent w/ Petcock			
HWS Hose End Drain Valve			
HWR Balancing Valve			
HWR Thermometer			
HWR Automatic Air Vent w/ Petcock			
HWR Hose End Drain Valve			
Coil Automatic Air Vent w/ Petcock			
Coil Hose End Drain Valve			
Piping Insulation Complete			
Piping Identification Installed			
Valve Tagging Complete			

Re-
marks:

21. Verify installation of HW coil freeze protection pump. Compliance: _____
Non-
compliance: _____

Remarks:

22. Freeze Pump Identification
Motor Performance:

HP	Voltage	Phase
		3

Nameplate FLA (amps) _____

23. Verify piping arrangement and support equipment to heating coil freeze pump per detail on drawing XXXXX:			
	Yes		***No***
Suction Side Isolation Valve			
Freeze Pump			
Discharge Side Isolation Valve			
Pressure Gauge w/ Shut-Off Valves			
Differential Pressure Switch (Status)			
By-Pass Line w/ Check Valve			

Remarks:

24. Verify installation of HWS/HWR manifold pressure gauge with petcocks per detail X on drawing XXXX.
    - Record gauge range and compare with speci-

Compliance: _____
Non-
compliance: _____

fication section XXXX.

Remarks:

25. Verify installation of supply and return fan variable speed drive(s) w/ HOA switch.
    - Record make and model.
    - Record minimum drive speed.

    Compliance: _____
    Non-compliance: _____

Remarks:

26. Verify installation of vibration isolation and seismic restraint as required per specification section XXXX.
    - Compare with vibration/seismic submittal.
    - Verify compliance with vibration/seismic engineer final report as required per specification section XXXX.

    Compliance: _____
    Non-compliance: _____

Remarks:

27. Verify all equipment (supply fan, return fan, air handling unit, VFD) have been labeled.

    Compliance: _____
    Non-compliance: _____

Remarks:

28. Verify installation of **supply** and **return** duct smoke detector(s) and associated remote test switches.
    - Verify multiple detectors have been installed as required per drawings.
    - Record location(s).

    Compliance:. _____
    Non-compliance: _____

Remarks:

29. Verify rooftop air handling unit is power under stand-by/emergency power per drawing XXXX:
    - Record panel designation.

    Compliance: _____
    Non-compliance: _____

Remarks:

PRODUCT DATA SHEET 2 - C. Functional Performance Testing

1. Verify start/stop capability and occupancy schedule operation through the BAS:
    - Record occupancy schedule parameters.

    Compliance: _____
    Non-compliance: _____

Remarks:

2. Verify installation/operation of the **return** air duct temperature sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The return air temperature sensor is calibrated within X deg F.***

3. Verify installation/operation of the **return** air duct relative humidity sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The return air humidity sensor is calibrated within X % RH.***

4. Verify installation/operation of the **return** duct CO_2 sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The return air CO_2 sensor is calibrated within X ppm.***

5. Verify installation/operation of the **return** duct static pressure sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The return duct static pressure sensor is calibrated within X inches.***

6. Verify installation/operation of the **mixed air** temperature sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The mixed air temperature sensor is calibrated within X deg F.***

7. Verify installation/operation of the **heating coil discharge air** temperature sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The discharge air temperature sensor is calibrated within X deg F.***

8. Verify installation/operation of the **supply** air duct temperature sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The supply air temperature sensor is calibrated within X deg F.***

9. Verify installation/operation of the **supply** air duct relative humidity sensor:
   - Verify calibration.
   - Record location.

   Compliance: _____
   Non-compliance: _____

   Remarks: ***The supply air humidity sensor is calibrated within X % RH.***

10. Verify installation/operation of the **supply air distribution system** duct static pressure sensor(s):
    - Verify calibration.
    - Record location.
    - Record setpoint.

    Compliance: _____
    Non-compliance: _____

    Remarks: ***The supply air distribution duct static pressure sensor are calibrated within X inches.***

11. Verify installation/operation of the **supply** airflow measuring station:
    - Verify calibration.
    - Record location.

    Compliance: _____
    Non-compliance: _____

    Remarks:

12. Verify installation/operation of the **return** airflow measuring station:
    - Verify calibration.
    - Record location.

    Compliance: _____
    Non-compliance: _____

    Remarks:

13. Verify installation/operation of the **outdoor air** airflow measuring station:
    - Verify calibration.
    - Record location.

    Compliance: _____
    Non-compliance: _____

    Remarks:

14. Verify operation of supply and return fan VFD w/ HOA switches.
    - Verify start/stop capability through the BAS.
    - Verify operation of HOA switch.

    Compliance: _____
    Non-compliance: _____

    Remarks:

15. Verify supply and return fan status is properly reported through the BAS.
    - Record parameters.

    Compliance: _____
    Non-compliance: _____

    Remarks:

16. Verify freeze pump status is properly reported through the BAS.
    - Record parameters.

Compliance: _____
Non-compliance: _____

Remarks:

17. Verify that the supply and return fans are interlocked with the smoke/isolation dampers.
    - Record parameters.

Compliance: _____
Non-compliance: _____

Remarks:

18. Verify outdoor air, return air and exhaust air damper operation through the BAS.
    - Record parameters for damper tracking.

Compliance: _____
Non-compliance: _____

Remarks:

Fan Performance

19. Record fan performance at full flow (60 Hz.) w/ all terminal boxes commanded open:
    a. Supply Fan
    b. Return Fan

Airflow (cfm)	Total Pressure (inches)	
	Inlet	Discharge

Remarks:

20. Record fan motor performance at full flow:
    a. Supply Fan
    b. Return Fan

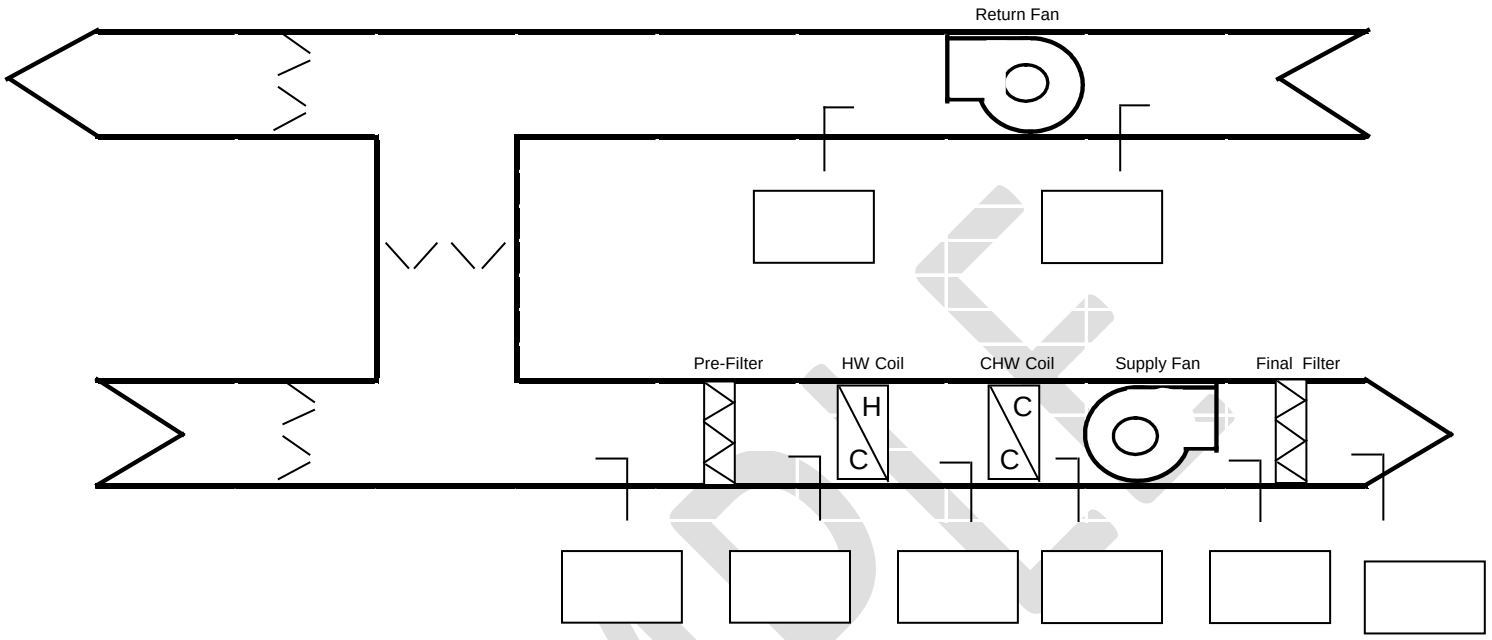
Voltage (volts)	Amperage (amps)	Frequency (Hz.)

Remarks:

21. Measure and record unit static pressure profile during full flow performance (see diagram below).

Compliance: _____
Non-compliance: _____

Remarks:



Unoccupied Mode

22. Verify unit operation during unoccupied mode when the **outdoor air temperature is above 45 deg F**. Verify the following occurs:
    - The supply and return fans are de-energized.
    - The outdoor air and exhaust air dampers are closed and the return air damper is open.
    - The heating coil and cooling coil control valves are commanded closed.
    - The freeze pump is commanded OFF.

    Compliance: _____
    Non-compliance: _____

    Remarks:

23. Verify unit operation during unoccupied mode when the **outdoor air temperature is below 45 deg F**. Verify the following occurs:
    - The supply and return fans are de-energized.
    - The outdoor air and exhaust air dampers are closed and the return air damper is open.
    - The cooling coil control valve is commanded closed.
    - The heating coil valve modulates open to maintain a mixed air temperature setpoint (65 deg F, adjustable).
    - The freeze pump is commanded ON.

    Compliance: _____
    Non-compliance: _____

Remarks:

Night Set-Up Mode

24. Verify unit operation during unoccupied cooling mode. Verify the following occurs:
    - If the average zone temperature rises above setpoint (80 deg F, adjustable) then the air handling unit will be indexed to occupied mode (see below).
    - Record final night setback temperature set-points (average zone temperature, etc.).

Compliance: _____
Non-compliance: _____

Remarks:

Night Set-Back Mode

25. Verify unit operation during unoccupied heating mode. Verify the following occurs:
    - If the average zone temperature drops below setpoint (65 deg F, adjustable) then the air handling unit will be indexed to occupied mode (see below).
    - Record final night setback temperature set-points (average zone temperature, etc.).

Compliance: _____
Non-compliance: _____

Remarks:

Occupied Mode

26. Verify unit operation during occupied mode. Verify the following occurs:
    - The supply fan is energized and modulates to maintain the duct static pressure setpoint.
    - The return fan is energized and modulates to maintain the SA/RA differential setpoint. Record setpoint.
    - The outdoor air damper will modulate open to maintain the minimum outdoor airflow set-point.
    - The return and exhaust/relief dampers will modulate to maintain design airflow.
    - The outdoor air damper, HW coil and CHW coil modulate, without overlap, to maintain the discharge air temperature setpoint.

Compliance: _____
Non-compliance: _____

Remarks: ***The supply and return fans are programmed to track 1:1 and are offset through the variable frequency drive offset (see fan performance above).***

CO_2 Control

27. Verify operation of CO_2 control mode sequence:
    - The BAS will modulate the outdoor air damper open to maintain the return air CO_2 setpoint.
    - Record final setpoint (1000 ppm, adjustable).

Compliance: _____
Non-compliance: _____

Remarks: ***The return air CO_2 setpoint has been set at 900 ppm through the ATC system. A return air CO_2 setpoint was not provided. Is current setpoint acceptable? Engineer to review and advise.***

If the measured value CO2 increases above setpoint then the mixing dampers begin to open and allow more outdoor air to enter the unit.

28. Verify that the CO_2 control mode is subject to a mixed air temperature low limit as measured by the mixed air temperature sensor.
    - Verify that the BAS modulates the dampers back to minimum outdoor air position.
    - Record final setpoint (55 deg F, adjustable).

Compliance: _____
Non-compliance: _____

Remarks: ***The mixing dampers are subject to a mixed air low limit of 40 deg F (10 deg F less then setpoint) as measured at the mixed air temperature sensor. If the mixed air temperature drops below setpoint then the dampers are indexed to minimum position.***

Hot Water Coil

29. Verify hot water heating coil maximum capacity (control valve 100% open, airflow set, etc.):
    - Record airflow, discharge air temperature, intake air temperature.

Compliance: _____
Non-compliance: _____

Remarks:

30. Verify operation of heating hot water coil control valve as it modulates to maintain setpoint:
    - Record parameters.
    - Record parameters regarding overlap prevention with chilled water coil control valve.

Compliance: _____
Non-compliance: _____

Remarks: ***The hot water coil, chilled water coil and economizer mode are all controlled through one temperature control PID loop.***

From 0% to 45% of the control PID loop the hot water coil valve is allowed to operate. The hot water coil control valve will modulate open to maintain a discharge air temperature setpoint of 50 deg F.

Chilled Water Coil

31. Verify chilled water cooling coil maximum capacity (control valve open, airflow set, etc.):
    - Record airflow, discharge air temperature/humidity, intake air temperature /humidity.

Compliance: _____
Non-compliance: _____

Remarks: ***Unable to verify under current season – to be verified during differed seasonal testing.***

32. Verify operation of chilled water coil control valve as it modulates to maintain setpoint:
    - Record parameters.
    - Record parameters regarding overlap prevention with hot water coil control valve.

Compliance: _____
Non-compliance: _____

Remarks: ***The hot water coil, chilled water coil and economizer mode are all controlled through one temperature control PID loop.***

From 65% to 100% of the control PID loop the chilled water coil valve is allowed to operate. The chilled water coil control valve will modulate open to maintain a discharge air temperature setpoint of 50 deg F.

Economizer Mode

33. Verify comparative enthalpy economizer operation:
    - The BAS will modulate the outdoor air damper above minimum position when the **outdoor air** enthalpy is **less** than the **return air** enthalpy.
    - The return damper will track accordingly.
    - The heating coil control valve and the cooling coil control valve are locked out of operation.

Compliance: _____
Non-compliance: _____

Remarks:

34. Verify that the chilled water coil, heating hot water coil and economizer operation modulate without overlap to maintain the discharge air temperature setpoint.
    - Record discharge air temperature setpoint.
    - Record parameters regarding overlap prevention.

Compliance: _____
Non-compliance: _____

Remarks: ***The hot water coil, chilled water coil and economizer mode are all controlled through one temperature control PID loop.***

From 50% to 65% of the control PID loop the mixed air dampers are allowed to modulate above minimum position (from minimum position to 100% open, if required). The economizer mode is enabled when the outdoor air enthalpy is less then the return air enthalpy.

35. Verify that the economizer mode is subject to a mixed air temperature low limit as measured by the mixed air temperature sensor.
    - Verify that the BAS modulates the dampers back to minimum outdoor air position.
    - Record final setpoint (55 deg F, adjustable).

Compliance: _____
Non-compliance: _____

Remarks: ***If the outdoor air temperature is above 50 deg F, the mixing dampers modulate to maintain the discharge air temperature setpoint. If the outdoor air temperature is below 50 deg F then the mixing dampers modulate to maintain mixed air temperature 2 deg F below the discharge air temperature setpoint.***

Alarms and Safeties

36. Verify supply fan failure condition on a loss of supply fan status:
    - The return fan is de-energized. The outdoor air damper is commanded closed and the return air damper is commanded open.
    - An alarm is generated at the facilities workstation.

Compliance: _____
Non-compliance: _____

Remarks:

37. Verify return fan failure condition on a loss of return fan status:
    - The supply fan is de-energized. The outdoor air damper is commanded closed and the return air damper is commanded open.
    - An alarm is generated at the facilities workstation.

Compliance: _____
Non-compliance: _____

Remarks:

38. Verify installation/operation of the **supply** duct high static pressure switch:
    - Verify calibration.
    - Record location.

Compliance: _____
Non-compliance: _____

Remarks:

39. Verify high duct static pressure condition when duct static pressure is above setpoint:
    - The supply and return fans are de-energized.

Compliance: _____
Non-compliance: _____

The outdoor air damper is commanded closed and the return air damper is commanded open.
- An alarm is generated at the facilities workstation.
- Record setpoint (3.5 inches, adjustable).

Remarks:

40. Verify installation/operation of the **dirty filter** differential pressure switches:
    - Verify calibration.
    - Record location.
    - Record setpoint.

    Compliance: _____ Non-compliance: _____

    Remarks:

41. Verify dirty filter condition when differential pressure is above setpoint:
    - An alarm is generated at the facilities workstation.

    Compliance: _____ Non-compliance: _____

    Remarks:

42. Verify installation/operation of the **freezestat** sensor(s):
    - Verify calibration.
    - Record location.
    - Record setpoint.

    Compliance: _____ Non-compliance: _____

    Remarks:

43. Verify freezestat condition when air temperature is below temperature setpoint :
    - The supply and return fans are de-energized. The outdoor air damper is commanded closed and the return air damper is commanded open.
    - The heating coil control valve is commanded 100% open.
    - An alarm is generated at the facilities workstation.
    - Record setpoint (38 deg F, adjustable).
    - Verify freezestat must be manually reset.

    Compliance: _____ Non-compliance: _____

    Remarks:

44. Verify that the activation of the **supply** and **return** duct smoke detectors will:
    - The supply and return fans are de-energized.

    Compliance: _____ Non-compliance: _____

- The outdoor air damper is commanded closed and the return air damper is commanded open.
- An alarm is generated at the facilities workstation.

Remarks:

45. Verify the following information is available and accurate at the operator's workstation:			
	Yes		***No***
a. Occupied/Unoccupied Schedule	X		
b. Occupied/Unoccupied Status	X		
c. Supply Fan Start/Stop	X		
d. Supply Fan Status	X		
e. Supply Fan Speed	X		
f. Return Fan Start/Stop	X		
g. Return Fan Status	X		
h. Return Fan Speed	X		
i. Outdoor Air Temperature	X		
j. Outdoor Air Relative Humidity	X		
k. Return Air CO2	X		
l. OA damper command	X		
m. OA damper position	X		
n. RA damper command	X		
o. RA damper position	X		
p. EA damper command	N/A		
q. EA damper position	N/A		
r. Mixed Air Temperature	X		
s. Discharge Air Static Pressure	X		
t. Discharge Air Static Pressure Setpoint	X		
u. Discharge Air Temperature	X		
v. Discharge Air Temperature Setpoint	X		
w. Hot Water Coil Valve Position	X		
x. Chilled Water Coil Valve Position	X		
y. Outdoor Airflow Setpoint	X		
z. Graphic Display	X		

Remarks: ***The dampers do not provide a feedback signal indicating damper position. The dampers value on the graphic display indicates the damper command only.***

Notes:

END OF TEST