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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2011

SECTION 23 08 00.00 10

COMMISSIONING OF HVAC SYSTEMS 01/08

NOTE: This guide specification covers the requirements for commissioning of HVAC systems.

Adhere to [UFC 1-300-02](#) Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a [Criteria Change Request \(CCR\)](#).

PART 1 GENERAL

NOTE: Use of this specification is mandatory for all projects. A properly functioning HVAC system assures a comfortable, healthy and productive environment for the user. The "Design Agent's Representative" will be a member of the HVAC design team, i.e. from the AE or Engineering Division. The "Design Agent's Representative" will actively participate in the process, including review of all submittals contained herein.

1.1 REFERENCES

NOTE: This paragraph is used to list the publications cited in the text of the guide

specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASSOCIATED AIR BALANCE COUNCIL (AABC)

ACG Commissioning Guideline (2005) Commissioning Guideline

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

NEBB Commissioning Standard (2009) Procedural Standards for Whole Building Systems Commissioning of New Construction; 3rd Edition

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA 1429 (1994) HVAC Systems Commissioning Manual, 1st Edition

U.S. GREEN BUILDING COUNCIL (USGBC)

LEED (2002; R 2005) Leadership in Energy and Environmental Design(tm) Green Building Rating System for New Construction (LEED-NC)

1.2 DEFINITIONS

In some instances, terminology differs between the Contract and the Commissioning Standard primarily because the intent of this Section is to use the industry standards specified, along with additional requirements listed herein to produce optimal results. The following table of similar terms is provided for clarification only. Contract requirements take precedent over the corresponding ACG, NEBB, or TABB requirements where differences exist.

SIMILAR TERMS			
Contract Term	ACG	NEBB	TABB
Commissioning Standard	ACG Commissioning Guideline	Procedural Standards for Building Systems Commissioning	SMACNA HVAC Commissioning Guidelines
Commissioning Specialist	ACG Certified Commissioning Agent	NEBB Qualified Commissioning Administrator	TABB Certified Commissioning Supervisor

1.3 SYSTEM DESCRIPTION

1.3.1 General

Perform Commissioning in accordance with the requirements of the standard under which the Commissioning Firm's qualifications are approved, i.e., **ACG Commissioning Guideline**, **NEBB Commissioning Standard**, or **SMACNA 1429** unless otherwise stated herein. Consider mandatory all recommendations and suggested practices contained in the Commissioning Standard. Use the Commissioning Standard for all aspects of Commissioning, including qualifications for the Commissioning Firm and Specialist and calibration of Commissioning instruments. Where the instrument manufacturer calibration recommendations are more stringent than those listed in the Commissioning Standard, the manufacturer's recommendations shall be adhered to. All quality assurance provisions of the Commissioning Standard such as performance guarantees shall be part of this contract. For systems or system components not covered in the Commissioning Standard, Commissioning procedures shall be developed by the Commissioning Specialist. Where new procedures, requirements, etc., applicable to the Contract requirements have been published or adopted by the body responsible for the Commissioning Standard used (ACG, NEBB, or TABB), the requirements and recommendations contained in these procedures and requirements shall be considered mandatory.

1.3.2 Energy

Formal **LEED** certification is not required; however, the Contractor is required to provide documentation that meets the **LEED** Energy & Atmosphere (EA) Prerequisite 1, Fundamental Commissioning. For New Construction and Major Revisions provide, also, documentation that meets EA Credit 3; Enhanced Commissioning. Provide documentation for as many LEED credits as possible to support LEED Silver certification of the project.

1.4 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some

submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Commissioning Plan[; G,][;G, [____]]

SD-03 Product Data

Pre-Functional Performance Test Checklists[; G,][;G, [____]]
Functional Performance Tests[; G,][;G, [____]]

SD-06 Test Reports

Commissioning Report[; G][; G, [____]]

SD-07 Certificates

Commissioning Firm[; G][; G, [____]]
Commissioning Specialist[; G][; G, [____]]

1.5 QUALITY ASSURANCE

1.5.1 Commissioning Firm

Submit certification of the proposed Commissioning Firm's qualifications to perform the duties specified herein and in other related Sections, no later than 21 days after the Notice to Proceed. Include in the documentation the date that the Certification was initially granted and the date when the current Certification expires. The firm is either a member of ACG or

certified by the NEBB or the TABB and certified in all categories and functions where measurements or performance are specified on the plans and specifications. Any lapses in Certification of the proposed Commissioning Firm or disciplinary action taken by ACG, NEBB, or TABB against the proposed Commissioning Firm shall be described in detail. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the firm loses subject certification during this period, immediately notify the Contracting Officer and submit another Commissioning Firm for approval. Any firm that has been the subject of disciplinary action by the ACG, the NEBB, or the TABB within the five years preceding Contract Award is not eligible to perform any duties related to the HVAC systems, including Commissioning. All work specified in this Section and in other related Sections to be performed by the Commissioning Firm shall be considered invalid if the Commissioning Firm loses its certification prior to Contract completion and must be performed by an approved successor. These Commissioning services are to assist the prime Contractor in performing the quality oversight for which it is responsible. The Commissioning Firm shall be a subcontractor of the prime Contractor and shall be financially and corporately independent of all other subContractors. The Commissioning Firm shall report to and be paid by the prime Contractor.

1.5.2 Commissioning Specialist

1.5.2.1 General

Submit certification of the proposed Commissioning Specialist's qualifications to perform the duties specified herein and in other related Sections, no later than 21 days after the Notice to Proceed. The documentation shall include the date that the Certification was initially granted and the date when the current Certification expires. The Commissioning Specialist shall be an ACG Certified Commissioning Agent, a NEBB Qualified Commissioning Administrator, or a TABB Certified Commissioning Supervisor and shall be an employee of the approved Commissioning Firm. Any lapses in Certification of the proposed Commissioning Specialist or disciplinary action taken by ACG, NEBB, or TABB against the proposed Commissioning Specialist shall be described in detail. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the Commissioning Specialist loses subject certification during this period, immediately notify the Contracting Officer and submit another Commissioning Specialist for approval. Any individual that has been the subject of disciplinary action by the ACG, the NEBB, or the TABB within the five years preceding Contract Award is not eligible to perform any duties related to the HVAC systems, including Commissioning. All work specified in this Section and in other related Sections performed by the Commissioning Specialist shall be considered invalid if the Commissioning Specialist loses certification prior to Contract completion and must be performed by the approved successor.

1.5.2.2 Responsibilities

Perform all Commissioning work specified herein and in related sections under the direct guidance of the Commissioning Specialist. The Commissioning Specialist shall prepare, no later than 28 days after the approval of the Commissioning Specialist, the [Commissioning Plan](#) which will be a comprehensive schedule and will include all submittal requirements for procedures, notifications, reports and the Commissioning Report. After approval of the Commissioning Plan, revise the Contract NAS schedule to

reflect the schedule requirements in the Commissioning Plan.

1.6 SEQUENCING AND SCHEDULING

Begin the work described in this Section only after all work required in related Sections has been successfully completed, and all test and inspection reports and operation and maintenance manuals required in these Sections have been submitted and approved. Pre-Functional Performance Test Checklists shall be performed at appropriate times during the construction phase of the Contract.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

3.1 COMMISSIONING TEAM AND TEST FORMS AND CHECKLISTS

NOTE: The "Design Agent's Representative" will be included as a member of the commissioning team for the pre-commissioning checklists and will participate in the functional performance tests.

The checklists provided are to be used as guides for the preparation of project checklists. The appropriate checklist should be included in the project specification for each HVAC equipment component. The designer will add additional checklists for equipment or systems not included in this guide specification or modify the checklists where necessary for specific project requirements. If, for example, a system needs to be tested with certain internal load, each appropriate checklist should be modified to include this requirement along with specifics on how load should be generated.

Designate Contractor team members to participate in the Pre- Functional Performance Test Checklists and the Functional Performance Tests specified herein. In addition, the Government team members will include a representative of the Contracting Officer, the Design Agent's Representative, and the Using Agency's Representative. The team members shall be as follows:

Designation	Function
A	Contractor's Commissioning Specialist
M	Contractor's Mechanical Representative
E	Contractor's Electrical Representative
T	Contractor's Testing, Adjusting, and Balancing (TAB) Specialist

Designation	Function
C	Contractor's Controls Representative
D	Design Agency Representative
O	Contracting Officer's Representative
U	Using Agency's Representative

Appendices A and B shall be completed by the commissioning team. Acceptance by each commissioning team member of each Pre- Functional Performance Test Checklist item shall be indicated by initials and date unless an "X" is shown indicating that participation by that individual is not required. Acceptance by each commissioning team member of each functional performance test item shall be indicated by signature and date.

3.2 TESTS

Perform the pre-functional performance test checklists and functional performance tests in a manner that essentially duplicates the checking, testing, and inspection methods established in the related Sections. Where checking, testing, and inspection methods are not specified in other Sections, establish methods which will provide the information required. Testing and verification required by this section shall be performed during the Commissioning phase. Requirements in related Sections are independent from the requirements of this Section and shall not be used to satisfy any of the requirements specified in this Section. Provide all materials, services, and labor required to perform the pre- functional performance tests checks and functional performance tests. A functional performance test shall be aborted if any system deficiency prevents the successful completion of the test or if any participating non-Government commissioning team member of which participation is specified is not present for the test.

3.2.1 Pre-Functional Performance Test Checklists

Perform Pre-Functional Performance Test Checklists, for the items indicated in Appendix A, at least 28 days prior to the start of Pre-Functional Performance Test Checks.. Correct and re-inspect deficiencies discovered during these checks in accordance with the applicable contract requirements. Submit the schedule for the test checks at least 14 days prior to the start of Pre-Functional Performance Test Checks.

3.2.2 Functional Performance Tests

Submit test procedures at least 28 days prior to the start of Functional Performance Tests. Submit the schedule for the tests at least 14 days prior to the start of Functional Performance Tests. Perform Functional Performance Tests for the items indicated in Appendix B. Begin Functional Performance Tests only after all Pre-Functional Performance Test Checklists have been successfully completed. Tests shall prove all modes of the sequences of operation, and shall verify all other relevant contract requirements. Begin Tests with equipment or components and progress through subsystems to complete systems. Upon failure of any Functional Performance Test item, correct all deficiencies in accordance with the applicable contract requirements. The item shall then be retested until it has been completed with no errors.

3.3 COMMISSIONING REPORT

Submit the Commissioning Report, no later than 14 days after completion of Functional Performance Tests, consisting of completed Pre- Functional Performance Test Checklists and completed Functional Performance Tests organized by system and by subsystem and submitted as one package. The Commissioning Report shall also include all HVAC systems test reports, inspection reports (Preparatory, Initial and Follow-up inspections), start-up reports, TAB report, TAB verification report, Controls start-up test reports and Controls Performance Verification Test (PVT) report. The results of failed tests shall be included along with a description of the corrective action taken.

APPENDIX A

PRE-FUNCTIONAL PERFORMANCE TEST CHECKLISTS

Pre-Functional Performance Test Checklist - Multizone Air Handling Unit

For Air Handling Unit: [_____]

Checklist Item	A	M	E	T	C	O
Installation						
a. Inspection and access doors are operable and sealed.	___	___	X	___	X	___
b. Condensate drainage is unobstructed. (Visually verify pan drains completely by pouring a cup of water into drain pan.)	___	___	X	X	X	___
c. Fan belt adjusted.	___	___	X	___	X	___

Electrical	A	M	E	T	C	O
a. Power available to unit disconnect.	___	X	___	X	X	___
b. Power available to unit control panel.	___	X	___	X	X	___
c. Proper motor rotation verified.	___	X	___	___	X	___
d. Verify that power disconnect is located within sight of the unit it controls.	___	X	___	X	X	___
[e. Power available to electric heating coil.	___	X	___	X	X	___]

Coils	A	M	E	T	C	O
[a. Chilled water piping properly connected.	___	___	X	X	X	___]
[a. Refrigerant piping properly connected.	___	___	X	X	X	___]
[b. Hot water piping properly connected.	___	___	X	X	X	___]
[b. Steam and condensate piping properly connected.	___	___	X	X	X	___]

Controls	A	M	E	T	C	O
a. Control valves/actuators properly installed.	___	X	X	X	___	___
b. Control valves/actuators operable.	___	X	X	X	___	___
c. O/A dampers/actuators properly installed.	___	X	X	X	___	___
d. O/A dampers/actuators operable.	___	X	X	X	___	___

Pre-Functional Performance Test Checklist - Multizone Air Handling Unit
(cont)

A M E T C O

e. Zone dampers/actuators properly installed & dampers leak checked.	___	X	X	X	___	___
f. Zone dampers/actuators operable.	___	X	X	X	___	___
Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. Construction filters removed and replaced.	___	___	X	___	X	___
b. TAB report approved.	___	___	X	X	___	X

Pre-Functional Performance Test Checklist - Variable Volume Air Handling Unit

For Air Handling Unit: [_____]

Checklist Item	A	M	E	T	C	O
Installation						
a. Inspection and access doors are operable and sealed.	___	___	X	___	X	___
b. Condensate drainage is unobstructed. (Visually verify drainage by pouring a cup of water into drain pan.)	___	___	X	X	X	___
c. Fan belt adjusted.	___	___	X	___	X	___
Electrical						
a. Power available to unit disconnect.	___	X	___	X	X	___
b. Power available to unit control panel.	___	X	___	X	X	___
c. Proper motor rotation verified.	___	X	___	___	X	___
d. Verify that power disconnect is located within sight of the unit it controls.	___	X	___	X	X	___
[e. Power available to electric heating coil.	___	X	___	X	X	___]
Coils						
[a. Chilled water piping properly connected.	___	___	X	X	X	___]
[a. Refrigerant piping properly connected.	___	___	X	X	X	___]
[b. Hot water piping properly connected.	___	___	X	X	X	___]
[b. Steam and condensate piping properly connected.	___	___	X	X	X	___]

Pre-Functional Performance Test Checklist - Variable Volume Air Handling Unit

Controls	A	M	E	T	C	O
a. Control valves/actuators properly installed.	___	X	X	X	___	___
b. Control valves/actuators operable.	___	X	X	X	___	___
c. Dampers/actuators properly installed.	___	X	X	X	___	___
d. Dampers/actuators operable.	___	X	X	X	___	___
e. Verify proper location, installation and calibration of duct static pressure sensor.	___	X	X	X	___	___
f. Fan air volume controller operable.	___	X	X	X	___	___
g. Air handler controls system operational.	___	X	X	X	___	___
Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. Construction filters removed and replaced.	___	___	X	___	___	___
b. TAB report approved.	___	X	X	___	X	___

Pre-Functional Performance Test Checklist - VAV Terminal

For VAV Terminal: [_____]

Checklist Item	A	M	E	T	C	O
Installation						
[a. Reheat coil connected to hot water pipe.	___	___	X	___	X	___]
[b. Electric reheat coil connected to local disconnect.	___	X	___	___	X	___]
Controls						
a. Cooling only VAV terminal controls set.	___	X	X	X	___	___
b. Cooling only VAV controls verified.	___	X	X	X	___	___
c. Reheat VAV terminal controls set.	___	X	X	X	___	___
d. Reheat terminal/coil controls verified.	___	X	X	X	___	___
Testing, Adjusting, and Balancing (TAB)						
a. TAB report approved.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - DX Air Cooled Condensing Unit
 For Condensing Unit: [_____]

Checklist Item	A	M	E	T	C	O
Installation						
a. Check condenser fans for proper rotation.	___	___	X	___	X	___
Electrical						
a. Power available to unit disconnect.	___	X	___	X	X	___
b. Power available to unit control panel.	___	X	___	X	___	___
c. Verify that power disconnect is located within sight of the unit it controls	___	X	___	X	___	___
Controls						
a. Unit safety/protection devices tested.	___	___	X	X	___	___
b. Control system and interlocks installed.	___	___	X	X	___	___
c. Control system and interlocks operational.	___	___	X	X	___	___

Pre-Functional Performance Test Checklist - Pumps

For Pump: [_____]

Checklist Item

A M E T C O

Installation

a. Piping system installed.

___ ___ X X X ___

Electrical

A M E T C O

a. Power available to pump disconnect.

___ X ___ X X ___

b. Pump rotation verified.

___ X ___ X X ___

c. Control system interlocks functional.

___ X ___ X ___ ___

Testing, Adjusting, and Balancing (TAB)

A M E T C O

a. Pressure/temperature gauges installed.

___ ___ X ___ X ___

b. TAB Report approved.

___ ___ X ___ X ___

Pre-Functional Performance Test Checklist - Packaged Air Cooled Chiller

For Chiller: [_____]

Checklist Item

A M E T C O

Installation

a. Chiller properly piped.

___ ___ X ___ ___ ___

Electrical

A M E T C O

a. Power available to unit disconnect.

___ X ___ X ___ ___

b. Power available to unit control panel.

___ X ___ X ___ ___

c. Separate power is supplied to electric heating tape.

___ X ___ X ___ ___

d. Verify that power disconnect is located within sight of the unit it controls.

___ X ___ X ___ ___

Controls

A M E T C O

a. Factory startup and checkout complete.

___ ___ X X ___ ___

b. Chiller safety/protection devices tested.

___ ___ X X ___ ___

c. Chilled water flow switch installed.

___ ___ X X ___ ___

d. Chilled water flow switch tested.

___ ___ X X ___ ___

e. Chilled water pump interlock installed.

___ ___ X X X ___

f. Chilled water pump interlock tested.

___ ___ ___ X

Pre-Functional Performance Test Checklist - Centrifugal Chiller

For Chiller: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Chilled water connections properly piped.	___	___	X	___	___	___
b. Condenser water connections properly piped	___	___	X	___	___	___
c. Refrigerant leak detector installed.	___	___	___	___	___	___
[d. Oxygen sensor installed and tested.	___	___	___	___	___	___]
e. Mechanical room ventilation installed as specified.	___	___	___	___	___	___
Electrical	A	M	E	T	C	O
a. Power available to unit starter.	___	X	___	X	___	___
b. Power available to unit control panel.	___	X	___	X	___	___
c. Verify that power disconnect is located within sight of the unit it controls.	___	X	___	X	___	___
Controls	A	M	E	T	C	O
a. Factory startup and checkout complete.	___	___	X	X	___	___
b. Chiller safety/protection devices tested.	___	___	___	X	___	___
c. Chilled water flow switch installed and tested.	___	___	X	X	___	___
e. Chilled water pump interlock installed and tested.	___	___	___	X	___	___
g. Condenser water flow switch installed and tested.	___	___	___	X	___	___
i. Condenser water pump interlock installed and tested.	___	___	___	X	___	___

Pre-Functional Performance Test Checklist - Cooling Tower

For Cooling Tower: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Cooling tower properly piped.	___	___	X	X	___	___
b. Cooling tower fan drive adjusted.	___	___	___	___	X	___
c. Cooling tower makeup water supply piped.	___	___	X	X	___	___
d. Verify makeup control valve shutoff.	___	___	X	___	X	___
e. Fan lubricated and blade pitch adjusted.	___	___	X	___	X	___

Electrical	A	M	E	T	C	O
a. Power available to tower disconnect.	___	X	___	X	___	___
b. Power available to electric sump heater.	___	X	___	X	___	___
c. Control system interlocks functional.	___	___	___	X	___	___
d. Motor and fan rotation checked.	___	X	___	X	___	___
e. Verify that power disconnect is located within sight of the unit is controls.	___	X	___	X	___	___

Piping	A	M	E	T	C	O
a. Condenser water treatment functional.	___	___	X	X	X	___
b. All required temperature sensing wells, pressure ports and flow sensors have been installed for performance tests.	___	___	___	___	___	___

Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB report approved.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - Hot Water Boiler

For Boiler: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Boiler hot water piping installed.	___	___	X	___	___	___
b. Boiler makeup water piping installed.	___	___	X	___	___	___
c. Boiler fuel oil piping installed.	___	___	X	X	X	___
d. Boiler gas piping installed.	___	___	X	X	X	___
Startup	A	M	E	T	C	O
a. Boiler safety/protection devices, including high temperature burner shut-off, low water cutoff, flame failure, pre- and post-purge, have been tested.	___	___	___	X	___	___
b. Verify that PRV rating conforms to boiler rating.	___	___	___	X	___	___
c. Boiler water treatment system functional.	___	___	X	X	___	___
d. Boiler startup and checkout complete.	___	___	X	X	___	___
e. Combustion efficiency demonstrated.	___	___	X	___	X	___
Electrical	A	M	E	T	C	O
a. Verify that power disconnect is located within sight of the unit served.	___	X	___	X	___	___
Controls	A	M	E	T	C	O
a. Hot water pump interlock installed and tested.	___	___	___	X	___	___
b. Hot water proof-of-flow switch installed and tested	___	___	X	X	___	___
c. Hot water heating controls operational.	___	___	X	X	___	___
Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB report approved.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - Steam Boiler

For Boiler: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Boiler steam piping installed.	___	___	X	X	X	___
b. Boiler makeup water piping installed.	___	___	X	___	X	___
c. Boiler fuel oil piping installed.	___	___	X	X	X	___
d. Boiler gas piping installed.	___	___	X	X	X	___

Startup	A	M	E	T	C	O
a. Boiler safety/protection devices, including high temperature burner shut-off, low water cutoff, flame failure, pre and post purge, have been tested.	___	___	___	X	___	___
b. Verify that PRV rating conforms to boiler rating.	___	___	___	X	___	___
c. Boiler feed water system operational.	___	___	___	X	___	___
d. Boiler water treatment system functional.	___	___	X	X	X	___
e. Boiler startup and checkout complete.	___	___	___	X	___	___
f. All steam traps operational.	___	___	X	X	X	___
g. All condensate return pumps operational.	___	___	___	___	X	___
h. Combustion efficiency demonstrated.	___	___	X	___	X	___

Electrical	A	M	E	T	C	O
a. Verify that power disconnect is located within sight of the unit served.	___	X	___	X	___	___

Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB report approved.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - Steam/Hot Water Converter

For Converter: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Converter steam piping installed.	___	___	X	___	X	___
b. Hot water piping installed.	___	___	X	___	___	___
c. Makeup water piping installed.	___	___	X	X	X	___
d. Vacuum breaker installed on shell of shell and tube unit.	___	___	X	X	X	___
Startup	A	M	E	T	C	O
a. All steam traps operational.	___	___	X	X	X	___
b. All condensate return pumps operational.	___	___	___	X	___	___
c. Converter safety/protection devices tested.	___	___	X	X	X	___
d. Converter startup and checkout complete.	___	___	X	X	X	___
Controls	A	M	E	T	C	O
a. Control valves/actuators properly installed.	___	___	X	___	___	___
b. Control valves/actuators operable.	___	___	X	___	___	___

Pre-Functional Performance Test Checklist - Fan Coil Unit

For Fan Coil Unit: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Access doors/removable panels are operable and sealed.	___	___	X	___	X	___
b. Condensate drainage is unobstructed.	___	___	X	X	X	___
c. Fan belt adjusted.	___	___	X	___	X	___
Electrical	A	M	E	T	C	O
a. Power available to unit disconnect.	___	___	___	X	___	___
b. Power available to unit control panel.	___	___	___	X	___	___
c. Proper motor rotation verified.	___	___	___	___	X	___
d. Verify that power disconnect is located within sight of the unit it controls.	___	___	___	X	___	___
[e. Power available to electric heating coil.	___	___	___	X	X	___]
Coils	A	M	E	T	C	O
[a. Dual temperature piping properly connected.	___	___	X	___	___	___]
[b. Chilled water piping properly connected.	___	___	X	X	X	___]
[c. Hot water piping properly connected.	___	___	X	___	___	___]
Controls	A	M	E	T	C	O
a. Control valves/actuators properly installed.	___	___	X	___	___	___
b. Control valves/actuators operable.	___	___	X	X	___	___
c. Verify proper location and installation of thermostat.	___	___	X	___	___	___
Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB Report approved.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - Unit Heater

For Unit Heater: [_____]

Checklist Item

Installation	A	M	E	T	C	O
[a. Hot water piping properly connected.	___	___	X	___	___	___]
[a. Steam and condensate piping properly connected.	___	___	X	X	X	___]

Electrical	A	M	E	T	C	O
a. Power available to unit disconnect.	___	___	___	X	___	___
b. Proper motor rotation verified.	___	___	___	X	X	___
c. Verify that power disconnect is located within sight of the unit it controls.	___	___	___	X	___	___
d. Power available to electric heating coil.	___	___	___	X	___	___

Controls	A	M	E	T	C	O
a. Control valves properly installed.	___	___	X	___	___	___
b. Control valves operable.	___	___	X	X	___	___
c. Verify proper location and installation of thermostat.	___	___	X	___	___	___

Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB Report approved.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - Exhaust Fan

For Exhaust Fan: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Fan belt adjusted.	___	___	X	___	X	___

Electrical	A	M	E	T	C	O
a. Power available to fan disconnect.	___	___	___	X	___	___
b. Proper motor rotation verified.	___	___	___	___	X	___
c. Verify that power disconnect is located within sight of the unit it controls.	___	___	___	X	___	___

Controls	A	M	E	T	C	O
a. Control interlocks properly installed.	___	___	___	X	___	___
b. Control interlocks operable.	___	___	___	X	___	___
c. Dampers/actuators properly installed.	___	___	X	___	___	___
d. Dampers/actuators operable.	___	___	X	___	___	___
e. Verify proper location and installation of thermostat.	___	___	X	___	___	___

Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB Report approved.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - Computer Room Unit

For Computer Room Unit: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Access doors are operable and sealed.	___	___	X	___	X	___
b. Condensate drainage is unobstructed and routed to floor drain.	___	___	X	X	X	___
c. Fan belt adjusted.	___	___	X	___	X	___
Electrical	A	M	E	T	C	O
a. Power available to unit disconnect.	___	X	___	X	X	___
b. Proper motor rotation verified.	___	X	___	___	X	___
c. Proper motor rotation verified.	___	X	___	___	X	___
d. Verify that power disconnect is located within sight of the unit it controls.	___	X	___	X	___	___
[e. Power available to reheat coils.	___	X	___	___	X	___]
Coils/Humidifier	A	M	E	T	C	O
[a. Chilled water piping properly connected.	___	___	X	___	___	___]
[a. Refrigerant piping properly connected.	___	___	X	X	X	___]
[b. Hot water piping properly connected.	___	___	X	___	___	___]
[b. Steam piping properly connected.	___	___	X	X	X	___]
[c. Humidifier makeup water connected.	___	___	X	X	X	___]
Controls	A	M	E	T	C	O
a. Control valves operable.	___	___	X	X	___	___
b. Unit control system operable and verified.	___	___	___	X	___	___
c. Verify proper location and installation of thermostat.	___	___	X	___	___	___
Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB Report submitted.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - HVAC System Controls

For HVAC System: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Layout of control panel matches drawings.	___	___	X	X	___	___
b. Framed instructions mounted in or near control panel.	___	___	X	X	___	___
c. Components properly labeled (on inside and outside of panel).	___	___	X	X	___	___
d. Control components piped and/or wired to each labeled terminal strip.	___	___	X	X	___	___
e. EMCS connection made to each labeled terminal strip as shown.	___	___	X	X	___	___
f. Control wiring and tubing labeled at all terminations, splices, and junctions.	___	___	X	X	___	___

Main Power and Control Air

a. 120 volt AC power available to panel.	___	___	___	X	___	___
b. 138 kPa gauge20 psig compressed air available to panel.	___	___	X	X	___	___

Testing, Adjusting, and Balancing (TAB)

Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O
a. TAB Report submitted.	___	___	X	___	X	___

Pre-Functional Performance Test Checklist - Single Zone Air Handling Unit

For Air Handling Unit: [_____]

Checklist Item

Installation	A	M	E	T	C	O
a. Inspection and access doors are operable and sealed.	___	___	X	___	X	___
b. Condensate drainage is unobstructed.	___	___	X	X	X	___
c. Fan belt adjusted.	___	___	X	___	X	___
Electrical	A	M	E	T	C	O
a. Power available to unit disconnect.	___	___	___	X	X	___
b. Power available to unit control panel.	___	___	___	X	___	___
c. Proper motor rotation verified.	___	___	___	___	X	___
d. Verify that power disconnect is located within sight of the unit it controls.	___	___	___	X	___	___
e. Power available to electric heating coil.	___	___	___	X	___	___
Coils	A	M	E	T	C	O
[a. Chilled water piping properly connected.	___	___	X	___	___	___]
[a. Refrigerant piping properly connected.	___	___	X	X	X	___]
[c. Hot water piping properly connected.	___	___	X	___	___	___]
[c. Steam and condensate piping properly connected.	___	___	X	X	X	___]
Controls	A	M	E	T	C	O
a. Control valves/actuators properly installed.	___	___	X	___	___	___
b. Control valves/actuators operable.	___	___	X	___	___	___
c. Dampers/actuators properly installed.	___	___	X	___	___	___
d. Dampers/actuators operable.	___	___	X	___	___	___
e. Verify proper location and installation of thermostat.	___	___	X	___	___	___
Testing, Adjusting, and Balancing (TAB)	A	M	E	T	C	O

a. TAB Report approved.

___ ___ X ___ X ___

Pre-Functional Performance Test Checklist - Energy Recovery System

For Energy Recovery System: [_____]

Checklist Item

Installation

A M E T C O

a. Recovery system piping installed.

___ ___ X ___ X ___

Startup

A M E T C O

a. Startup and checkout complete.

___ ___ X X X ___

Controls

A M E T C O

a. Control valves/actuators properly installed.

___ ___ X ___ ___ ___

b. Control valves/actuators operable.

___ ___ X ___ ___ ___

- End of Appendix A -

APPENDIX B

FUNCTIONAL PERFORMANCE TESTS CHECKLISTS

Functional Performance Test - Pump []

NOTE: Prior to performing this test, for closed loop systems ensure that the system is pressurized and the make-up water system is operational, or for open loop systems ensure that the sumps are filled to the proper level.

1. Activate pump start using control system commands.

a. Verify correct operation in:

HAND_____ OFF_____ AUTO_____

b. Verify pressure drop across strainer:

Strainer inlet pressure _____ kPa gauge_{psig}

Strainer outlet pressure _____ kPa gauge_{psig}

c. Verify pump inlet/outlet pressure reading, compare to Testing, Adjusting, and Balancing (TAB) Report and pump design conditions.

	DESIGN	TAB	ACTUAL
Pump inlet pressure kPa gauge _{psig}	_____	_____	_____
Pump outlet pressure kPa gauge _{psig}	_____	_____	_____

d. Operate pump at shutoff and at 100 percent of designed flow when all components are in full flow. Plot test readings on pump curve and compare results against readings taken from flow measuring devices.

	SHUTOFF	100 percent
Pump inlet pressure kPa gauge _{psig}	_____	_____
Pump outlet pressure kPa gauge _{psig}	_____	_____
Pump flow rate L/s _{gpm}	_____	_____

	SETPOINT
Differential Pressure Transmitter	_____

Functional Performance Test (cont) - Pump []

e. For variable speed pumps, operate pump at shutoff (shutoff to be done in manual on variable speed drive at the minimum rpm that the system is being controlled at) and at minimum flow or when all components are in full by-pass. Plot test readings on pump curve and compare results against readings taken from flow measuring devices.

	SHUTOFF	100 percent
Pump inlet pressure kPa gauge	_____	_____
Pump outlet pressure kPa gauge	_____	_____
Pump flow rate L/s	_____	_____
	SETPOINT	
Differential Pressure Transmitter	_____	

2. Measure motor amperage each phase and voltage phase to phase and phase to ground for both the full flow and the minimum flow conditions. Compare amperage to nameplate FLA

a. Full flow:

Nameplate FLA	_____		
Amperage Phase 1	_____	Phase 2 _____	Phase 3 _____
Voltage Ph1-Ph2	_____	Ph1-Ph3 _____	Ph2-Ph3 _____
Voltage Ph1-gnd	_____	Ph2-gnd _____	Ph3-gnd _____

b. Minimum flow:

Amperage Phase 1	_____	Phase 2 _____	Phase 3 _____
Voltage Ph1-Ph2	_____	Ph1-Ph3 _____	Ph2-Ph3 _____
Voltage Ph1-gnd	_____	Ph2-gnd _____	Ph3-gnd _____

3. Note unusual vibration, noise, etc.

Functional Performance Test (cont) - Pump []

4. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Contracting Officer's Representative	_____
Design Agency Representative	_____
Using Agency's Representative	_____

Functional Performance Test - Centrifugal Chiller []

Note: If water-cooled chiller perform in conjunction with Cooling Tower test.

1. Demonstrate operation of chilled water system in accordance with specifications including the following: Start building air handler to provide load for chiller. Activate controls system chiller start sequence as follows:

- a. Time of day startup program initiates chiller start: _____
- b. Record outdoor air temperature: _____
- c. Start condenser water pump and establish condenser water flow. Verify chiller condenser water proof-of-flow switch operation. _____
- d. Start chilled water pump and establish chilled water flow. Verify chiller chilled water proof-of-flow switch operation. _____
- e. Verify control system energizes chiller start sequence. _____
- f. Verify chiller senses chilled water temperature above set point and control system activates chiller start. _____
- g. Verify functioning of "soft start" sequence. _____
- h. Record data in 2, 3 and 4 below on fully load chiller.
- i. Shut off air handling equipment to remove load on chilled water system. Verify chiller shutdown sequence is initiated and accomplished after load is removed. _____
- j. Restart air-handling equipment one minute after chiller shut down. Verify condenser water pump, cooling tower, and chiller restart sequence. _____

2. Verify chiller inlet/outlet pressure and flow reading, compare to Testing, Adjusting, and Balancing (TAB) Report, chiller design conditions, and chiller manufacturer's performance data.

	DESIGN	TAB REPORT	ACTUAL
Chiller inlet pressure kPa gauge	_____	_____	_____
Chiller outlet pressure kPa gauge	_____	_____	_____
Chiller flow L/sec	_____	_____	_____

3. Measure chiller amperage each phase and voltage phase to phase and phase to ground for both the fully loaded condition.

				Motor F/L AMPS
Amperage	Phase 1 _____	Phase 2 _____	Phase 3 _____	_____
Voltage	Ph1-Ph2 _____	Ph1-Ph3 _____	Ph2-Ph3 _____	

Voltage Ph1-gnd _____ Ph2-gnd_____ Ph3-gnd_____

Functional Performance Test (cont) - Centrifugal Chiller []

4. a. Record the following information: Design

Outdoor air temperature _____	deg	CF	
Ambient dry bulb temperature _____	deg	CF	_____
Entering chilled water temperature _____	deg	CF	_____
Leaving chilled water temperature _____	deg	CF	_____

b. Calculate chiller load at ambient conditions and compare to chiller rated capacity from manufacturer's literature. Calculated _____ KWsTon
Rated _____ KWsTon.

5. Unusual vibration, noise, etc.

6. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Contracting Officer's Representative	_____
Design Agency Representative	_____
Using Agency's Representative	_____

Functional Performance Test - Cooling Tower []

1. Demonstrate operation of the cooling tower in accordance with specification and the following:

a. Activate cooling tower fan start using control system command. This should first start condenser water pump, establish flow, delay fan start, as specified, to equalize flow in distribution basin and sump. Verify fan start after timed delay. _____

b. After chiller startup, control system should modulate bypass valve and two-speed fan motor to maintain condenser water set point. Verify function of bypass valve under varying loads. _____

c. Verify cooling tower interlock with chiller. _____

d. Verify makeup water float valve is functioning. _____

e. Activate chemical treatment feed valve, verify makeup of chemical treatment system, pump, and controls. _____

f. Record the following:

Entering water temperature _____ deg CF
Leaving water temperature: _____ deg CF
Measured water flow: _____ L/s gpm
Entering air wet bulb temperature: _____ deg CF

2. Compare results with test results from cooling tower specification test.

3.

a. Stop all building cooling equipment so that cooling tower pumps stop. Observe tower for at least 15 minutes and verify no overflow occurs _____.

b. Start cooling tower pumps in hand and observe pumps for air binding/cavitation , none allowed _____.

4.Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist _____

Contractor's Mechanical Representative _____

Contractor's Electrical Representative _____

Contractor's TAB Representative _____

Contractor's Controls Representative _____

Contracting Officer's Representative _____

Design Agency Representative _____

Using Agency's Representative _____

Functional Performance Test Checklist - VAV Terminals

The Contracting officer will select VAV terminals to be spot-checked during the functional performance test. The number of terminals selected shall not exceed 10 percent.

1. Functional Performance Test: Contractor shall demonstrate operation of selected VAV boxes in accordance with specifications including the following:

a. Cooling only VAV boxes:

(1) Verify VAV box response to room temperature set point adjustment. Turn thermostat to 3 degrees C 5 degrees F below ambient and measure maximum airflow. Turn thermostat to 3 degrees C 5 degrees F above ambient and measure minimum airflow.

	Setting	Measured	Design	
Maximum flow	[]	[]	[]	L/scfm
Minimum flow	[]	[]	[]	L/scfm

b. Cooling with reheat VAV boxes:

(1) Verify VAV box response to room temperature set point adjustment. Turn thermostat to 3 degrees C 5 degrees F above ambient and measure maximum airflow. Turn thermostat to 3 degrees C 5 degrees F below ambient and measure minimum airflow.

	Setting	Measured	Design	
Maximum flow	[]	[]	[]	L/scfm
Minimum flow	[]	[]	[]	L/scfm

(2) Verify reheat coil operation range (full closed to full open) by turning room thermostat 3 degrees C 5 degrees F above ambient _____.

With heating water system and boiler in operation providing design supply hot water temperature record the following:

Design HW supply temperature _____ deg CF
Actual HW supply temperature _____ deg CF
AHU supply air temperature _____ deg CF
VAV supply air temperature _____ deg CF
Calculate coil capacity and compare to design:
Design _____ WBTU/hr Actual _____ WBTU/hr

Functional Performance Test Checklist (cont)- VAV Terminals

c. Parallel Fan powered VAV boxes:

(1) Verify VAV box responses to call for heating via set point adjustment. Change from cooling set point to heating set point. Verify cooling damper closes to minimum position, blower fan energizes according to sequence of operation, and upon further drop in space temperature, heating coil activation. _____

With heating water system in operation providing design supply hot water temperature record the following:

Design HW supply temperature _____ deg CF
Actual HW supply temperature _____ deg CF
AHU supply air temperature _____ deg CF
VAV supply air temperature _____ deg CF
Calculate coil capacity and compare to design:
Design _____ WBTU/hr Actual _____ WBTU/hr

(2) Check primary air damper maximum/minimum flow settings and compare to actual measured flows.

	Setting	Measured	Design	
Maximum flow	[_____]	[_____]	[_____]	L/scfm
Minimum flow	[_____]	[_____]	[_____]	L/scfm

(3) Check blower fan flow. [_____] L/scfm

(4) Verify free operation of fan backdraft damper (insure no primary air is being discharged into plenum space).

d. Series Fan Powered VAV boxes

(1) Ensure VAV fan starts prior to AHU fan

(2) Verify VAV box response to sensor call for heating via set point adjustment. Change from cooling set point to heating set point. Verify cooling damper closes to minimum position and upon further drop in space temperature, heating coil activation. With heating water system and boiler in operation providing design supply hot water temperature record the following:

Design HW supply temperature _____ deg CF
Actual HW supply temperature _____ deg CF
AHU supply air temperature _____ deg CF
VAV supply air temperature _____ deg CF
Calculate coil capacity and compare to design:
Design _____ WBTU/hr Actual _____ WBTU/hr

(3) Check primary air damper maximum/minimum flow settings and compare to actual measured flows.

	Setting	Measured	Design	
Maximum flow	[_____]	[_____]	[_____]	L/scfm

Minimum flow [_____] [_____] [_____] L/scfm

Functional Performance Test Checklist (cont) - VAV Terminals

(4) Verify that minimal primary air is discharging into the plenum space when in full cooling mode.

(5) Verify that no plenum air is being induced from the plenum space into the supply air during full cooling by measuring supply air temperature and comparing to primary air temperature

Primary air temp _____ deg **CF**
Supply air temp _____ deg **CF**

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

	Signature and Date
Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Contracting Officer's Representative	_____
Design Agency Representative	_____
Using Agency's Representative	_____

Functional Performance Test Checklist - Variable Volume Air Handling Unit

For Air Handling Unit: [_____]

1. Functional Performance Test: Contractor shall verify operation of air handling unit in accordance with specification including the following:

a. Ensure that a slight negative pressure exists on inboard side of the outside air dampers throughout the operation of the dampers. Modulate OA, RA, and EA dampers from fully open to fully closed positions_____.

b. The following shall be verified [supply fan operating] [supply and return fans operating] mode is initiated:

(1) All dampers in normal position prior to fan start_____.

(2) All valves in normal position prior to fan start_____.

(3) System safeties allow start if safety conditions are met._____

(4) VAV fan controller shall "soft-start" fan. _____

(5) Modulate all VAV boxes to minimum air flow and verify that the static pressure does not exceed the high static pressure shutdown setpoint_____.

(6) Return all VAV boxes to auto _____.

c. Occupied mode of operation - economizer de-energized.

(1) Outside air damper at minimum position. _____

(2) Return air damper open. _____

(3) Relief air damper [at minimum position] [closed]. _____

(4) Chilled water control valve modulating to maintain leaving air temperature set point. Setpoint _____deg CF Actual _____deg CF

(5) Fan VAV controller receiving signal from duct static pressure sensor and modulating fan to maintain supply duct static pressure set point.
Setpoint _____kpainches-wg Actual _____kpainches-wg

d. Occupied mode of operation - economizer energized.

(1) Outside air damper modulated to maintain mixed air temperature set point. Setpoint _____deg CF, Actual _____deg CF, Outside air damper position _____%.

(2) Relief air damper modulates with outside air damper according to sequence of operation. Relief air damper position_____%.

(3) Chilled water control valve modulating to maintain leaving air temperature set point. Setpoint _____deg CF Actual _____deg CF

(4) Hot water control valve modulating to maintain leaving air

temperature set point. Setpoint _____deg CF Actual _____deg CF

Functional Performance Test Checklist (cont) - Variable Volume Air Handling Unit

(5) Fan VAV controller receives signal from duct static pressure sensor and modulates fan to maintain supply duct static pressure set point. Setpoint **kpainches-wg**_____ Actual **kpainches-wg**_____

e. Unoccupied mode of operation

(1) Observe fan starts when space temperature calls for heating and/or cooling. _____ Note: This does not apply to series boxes.

(2) All dampers in normal position. _____

(3) Verify space temperature is maintained as specified in sequence of operation. _____

f. The following shall be verified when the [supply fan off][supply and return fans off] mode is initiated:

(1) All dampers in normal position. _____

(2) All valves in normal position. _____

(3) Fan de-energizes. _____

g. Verify the chilled water coil control valve operation by setting all VAV's to maximum and minimum cooling.

Max Cooling

Supply air temp. _____ deg **CF** Verify cooling valve operation_____.

Min cooling

Supply air temp. _____ deg **CF** Verify cooling valve operation_____.

h. Verify safety shut down initiated by low temperature protection thermostat. _____

i. Verify occupancy schedule is programmed into time clock/UMCS_____.

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist _____

Contractor's Mechanical Representative _____

Contractor's Electrical Representative _____

Contractor's TAB Representative _____

Contractor's Controls Representative _____

Design Agency Representative _____

Contracting Officer's Representative

Using Agency's Representative

Functional Performance Test Checklist - Single Zone Air Handling Unit

For Air Handling Unit: [_____]

1. Functional Performance Test: Contractor shall verify operation of air handling unit in accordance with specification including the following:

a. Ensure that a slight negative pressure exists on inboard side of the outside air dampers throughout the operation of the dampers. Modulate OA, RA, and EA dampers from fully open to fully closed positions.

a. The following shall be verified when the [supply fan operating] [supply and return fans operating] mode is initiated:

(1) All dampers in normal position prior to fan start_____.

(2) All valves in normal position prior to fan start_____.

(3) System safeties allow start if safety conditions are met. ____

b. Occupied mode of operation - economizer de-energized.

(1) Outside air damper at minimum position._____

(2) Return air damper open._____

(3) Relief air damper [at minimum position] [closed]._____

(4) Chilled water control valve modulating to maintain space cooling temperature set point. Setpoint _____deg CF Actual _____deg CF

(5) Hot water control valve modulating to maintain space heating temperature set point input from outside air temperature controller. _____

c. Occupied mode of operation - economizer energized.

(1) Outside air damper modulated to maintain mixed air temperature set point. Setpoint _____deg CF Actual _____deg CF O/A damper position _____% Return Air Temperature _____deg CF Outside Air Temperature _____ deg CF

(2) Relief air damper modulates with outside air damper according to sequence of operation. Relief air damper position _____%

(3) Chilled water control valve modulating to maintain space cooling temperature set point. Setpoint _____deg CF Actual _____deg CF Return sensor overrides to normal operation.

d. Unoccupied mode of operation.

(1) Observe fan starts when space temperature calls for heating/cooling ____.

(2) All dampers in normal position. _____

(3) Verify low limit space temperature is maintained as specified in sequence of operation. _____

Functional Performance Test Checklist (cont) - Single Zone Air Handling Unit

e. The following shall be verified when the [supply fan off] [supply and return fans off] mode is initiated:

(1) All dampers in normal position. _____

(2) All valves in normal position. _____

(3) Fan de-energizes. _____

f. Verify cooling coil and heating coil operation by varying thermostat set point from cooling set point to heating set point and returning to cooling set point _____.

g. Verify safety shut down initiated by low temperature protection thermostat _____.

h. Verify occupancy schedule is programmed into time clock/UMCS _____.

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Design Agency Representative	_____
Contracting Officer's Representative	_____
Using Agency's Representative	_____

Functional Performance Test Checklist - Multi-zone Air Handling Unit

For Air Handling Unit: [_____]

1. Functional Performance Test: Contractor shall verify operation of air handling unit in accordance with specification including the following:

a. Ensure that a slight negative pressure exists on inboard side of the outside air dampers throughout the operation of the dampers. Modulate OA, RA, and EA dampers from fully open to fully closed positions.

b. The following shall be verified when the supply and return fans operating mode is initiated:

(1) All dampers in normal position. _____

(2) All valves in normal position. _____

(3) System safeties allow start if safety conditions are met. ____

b. Occupied mode of operation - economizer de-energized.

(1) Outside air damper at minimum position. _____

(2) Return air damper open. _____

(3) Relief air damper [at minimum position] [closed]. _____

(4) Chilled water control valve modulating to maintain cold deck supply air temperature set point. Setpoint _____deg CF Actual _____deg CF

(5) Hot water control valve modulating to maintain hot deck supply air temperature set point input from outside air temperature controller. Setpoint _____deg CF Actual _____deg CF O/A _____deg CF

c. Occupied mode of operation - economizer energized. Note outside air and return air temperature sensors may need to be simulated.

(1) Outside air damper modulates to maintain mixed air temperature set point. Setpoint _____deg CF Actual _____deg CF Return Air Temperature _____deg CF Outside Air Temperature _____deg CF

(2) Relief air damper modulates with outside air damper according to sequence of operation. _____

(3) Chilled water control valve modulating to maintain cold deck supply air temperature set point. Setpoint _____deg CF Actual _____deg CF

(4) Hot water control valve modulating to maintain hot deck supply air temperature set point input from outside air temperature controller. Setpoint _____deg CF Actual _____deg CF O/A _____deg CF Return temperature sensors to normal operation.

Functional Performance Test Checklist (cont) - Multi-zone Air Handling Unit

d. Unoccupied mode of operation note time clock and space temperature sensor may require simulation.
(4) Observe fan starts when space temperature calls for heating/cooling.
(5) All dampers in normal position. _____
(6) Verify low limit space temperature is maintained as specified in sequence of operation. _____

e. The following shall be verified when the supply and return fans off mode is initiated:

(1) All dampers in normal position. _____

(2) All valves in normal position. _____

(3) Fan de-energizes. _____

Note: return time clock and space temperature sensors to normal operation.

f. Verify zone damper operation by varying zone thermostat set points from cooling set point to heating set point and returning to cooling set point. _____

g. Verify safety shut down initiated by low temperature protection thermostat. _____

h. Index room thermostats to full cooling then to full heating. Measure and record cold deck, hot deck, and supply air temperatures and determine damper leakage for a minimum of 2 zones.

Cold deck temperature _____ degrees CF

Hot deck temperature _____ degrees CF

Zone _____

Zone _____ Supply Air Temperature at Max Cooling _____ deg CF

Zone _____ Supply Air Temperature at Max Heating _____ deg CF

Zone _____ Hot Deck Damper leakage at Max cooling _____ 1/SCFM

Zone _____ Cold Deck Damper leakage at Max heating _____ 1/SCFM

Zone _____

Zone _____ Supply Air Temperature at Max Cooling _____ deg CF

Zone _____ Supply Air Temperature at Max Heating _____ deg CF

Zone _____ Hot Deck Damper leakage at Max cooling _____ 1/SCFM

Zone _____ Cold Deck Damper leakage at Max heating _____ 1/SCFM

i. Verify occupancy schedule is programmed into time clock/UMCS _____.

Functional Performance Test Checklist (cont) - Multi-zone Air Handling Unit

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist

Contractor's Mechanical Representative

Contractor's Electrical Representative

Contractor's TAB Representative

Contractor's Controls Representative

Design Agency Representative

Contracting Officer's Representative

Using Agency's Representative

Functional Performance Test Checklist - Packaged Air Cooled Chiller

For Chiller: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of chilled water system in accordance with specifications including the following: Start building air handler to provide load for chiller. Activate controls system chiller start sequence as follows.

a. Start chilled water pump and establish chilled water flow. Verify chiller-chilled water proof-of-flow switch operation. _____
Record outdoor air temperature. _____

b. Verify control system energizes chiller start sequence. _____

c. Verify chiller senses chilled water temperature above set point and control system activates chiller start. Setpoint_____deg **CF** Actual_____deg **CF**

d. Verify functioning of "soft start" sequence. _____

e. Verify and record chiller data in accordance with 2, 3 and 4 below on fully loaded chiller.

f. Shut off air handling equipment to remove load on chilled water system. Verify chiller shutdown sequence is initiated and accomplished after load is removed. _____

g. Restart air handling equipment one minute after chiller shut down. Verify chiller restart sequence. _____

2. Verify chiller inlet/outlet pressure reading, compare to Testing, Adjusting, and Balancing (TAB) Report, chiller design conditions, and chiller manufacturer's performance data.

		DESIGN	TAB TEST	ACTUAL
Chiller inlet pressure	(kPa gauge)	_____	_____	_____
Chiller inlet pressure	(psig)	_____	_____	_____
Chiller outlet pressure	(kPa gauge)	_____	_____	_____
Chiller outlet pressure	(psig)	_____	_____	_____
Chiller flow	L/secGPM	_____	_____	_____

3. Verify chiller amperage each phase and voltage phase-to-phase and phase-to-ground.

				Motor F/L AMPS
Amperage	Phase 1 _____	Phase 2 _____	Phase 3 _____	_____
Voltage	Ph1-Ph2 _____	Ph1-Ph3 _____	Ph2-Ph3 _____	
Voltage	Ph1-gnd _____	Ph2-gnd _____	Ph3-gnd _____	

Functional Performance Test Checklist (cont) - Packaged Air Cooled Chiller

4.

a. Record the following information:

		Design
Outdoor air temperature _____	degrees CF	
Ambient dry bulb temperature _____	degrees CF	_____ degrees CF
Entering chilled water temperature _____	degrees CF	_____ degrees CF
Leaving chilled water temperature _____	degrees CF	_____ degrees CF

b. Calculate chiller load at ambient conditions and compare to chiller rated capacity from manufacturer's literature. Calculated _____ **KWsTon**
Rated _____ **KWsTon**.

5. Unusual vibration, noise, etc.

6. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Design Agency Representative	_____
Contracting Officer's Representative	_____
Using Agency's Representative	_____

Functional Performance Test Checklist - Air Cooled Condensing Unit

For Condensing Unit: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of refrigeration system in accordance with specifications including the following: Start building air handler to provide load for condensing unit. Activate controls system start sequence as follows.

a. Start air handling unit. Verify control system energizes condensing unit start sequence. _____

b. Verify and record data in 2 and 3 below.

c. Shut off air handling equipment to verify condensing unit de-energizes. _____

d. Restart air handling equipment one minute after condensing unit shut down. Verify condensing unit restart sequence. _____

2. Verify condensing unit amperage each phase and voltage phase to phase and phase to ground.

Motor Full-Load Amps _____

Amperage Phase 1 _____ Phase 2 _____ Phase 3 _____

Voltage Ph1-Ph2 _____ Ph1-Ph3 _____ Ph2-Ph3 _____

Voltage Ph1-gnd _____ Ph2-gnd _____ Ph3-gnd _____

3. Record the following information:

Ambient dry bulb temperature	_____	degrees CF
Suction pressure	_____	kPa gaugepsig
Discharge pressure	_____	kPa gaugepsig

4. Unusual vibration, noise, etc.

5. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist _____

Contractor's Mechanical Representative _____

Contractor's Electrical Representative _____

Contractor's TAB Representative _____

Contractor's Controls Representative _____

Design Agency Representative _____

Contracting Officer's Representative _____

Using Agency's Representative

Functional Performance Test Checklist - Hot Water Boiler

For Boiler: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of hot water system in accordance with specifications including the following: Start building heating equipment to provide load for boiler. Activate controls system boiler start sequence as follows.

a. Start hot water pump and establish hot water flow. Verify boiler hot water proof-of-flow switch operation. _____
Record outdoor air temperature. _____

b. Verify control system energizes boiler start sequence. _____

c. Verify boiler senses hot water temperature below set point and control system activates boiler start. Setpoint _____ deg **CF**

2. Verify boiler inlet/outlet pressure reading, compare to Test and Balance (TAB) Report, boiler design conditions, and boiler manufacturer's performance data.

	DESIGN	SYSTEM TEST	ACTUAL
Boiler inlet water temperature deg CF	_____	_____	_____
Boiler outlet water temperature deg CF	_____	_____	_____
Boiler outlet pressure kPa gauge psig	_____	_____	_____
Boiler flow rate L/s gpm	_____	_____	_____
Flue-gas temperature at boiler outlet deg CF	_____	_____	_____
Percent carbon dioxide in flue-gas	_____	_____	_____
Draft at boiler flue-gas exit kPa inches-wg	_____	_____	_____
Stack emission pollutants concentration	_____	_____	_____
Fuel type	_____	_____	_____
Combustion efficiency	_____	_____	_____

3. Record the following information:

Ambient dry bulb temperature to determine reset schedule _____ degrees **CF**
Building Entering hot water temperature _____ degrees **CF**
Building Leaving hot water temperature _____ degrees **CF**

4. Verify temperatures in item 3 are in accordance with the reset schedule. _____

5. Verify proper operation of boiler safeties. _____
a. Low water _____
b. Water flow _____
c. Flame failure _____
d. Pilot failure _____
e. Pre and Post Purge failure _____
f. Pressure relief _____
g. High temperature _____

6. Shut off building heating equipment to remove load on hot water system. Verify boiler shutdown sequence is initiated and accomplished after load is removed. _____

Functional Performance Test Checklist (cont) - Hot Water Boiler

7. Unusual vibration, noise, etc.

8. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist

Contractor's Mechanical Representative

Contractor's Electrical Representative

Contractor's TAB Representative

Contractor's Controls Representative

Design Agency Representative

Contracting Officer's Representative

Using Agency's Representative

Functional Performance Test Checklist - Steam Boiler

For Boiler: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of steam heating system in accordance with specifications including the following: Start building heating equipment to provide load for boiler. Activate controls system boiler start sequence as follows.

a. Start steam heating system. Verify control system energizes boiler start sequence. _____
Record the outdoor air temperature. _____

b. Verify boiler senses steam pressure below set point and control system activates boiler start. _____

c. Shut off building heating equipment to remove load on steam heating system. Verify boiler shutdown sequence is initiated and accomplished after load is removed. _____

d. Verify that water level and makeup water system are operational.

2. Verify boiler inlet/outlet pressure reading, compare to boiler design conditions and manufacturer's performance data.

	DESIGN	SYSTEM TEST	ACTUAL
Boiler inlet feedwater temp deg CF	_____	_____	_____
Boiler outlet pressure kPa gauge	_____	_____	_____
Flue-gas temperature at boiler outlet deg CF	_____	_____	_____
Percent carbon dioxide in flue-gas	_____	_____	_____
Draft at boiler flue-gas exit kPa inches-wg	_____	_____	_____
Stack emission pollutants concentration	_____	_____	_____
Fuel type	_____	_____	_____
Combustion efficiency	_____	_____	_____

3. Record the following information:

Ambient temperature _____ deg CF

4. Verify proper operation of boiler safeties. _____

5. Unusual vibration, noise, etc.

6. Visually check refractory for cracks or spalling and refractory and tubes for flame impingement. _____

Functional Performance Test Checklist (cont) - Steam Boiler

7. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Design Agency Representative	_____
Contracting Officer's Representative	_____
Using Agency's Representative	_____

Functional Performance Test Checklist - Fan Coil Units

The Contracting Officer will select fan coil units to be spot-checked during the functional performance test. The number of terminals shall not exceed 10 percent. Hot water and chilled water systems must be in operation providing design water temperatures.

1. Functional Performance Test: Contractor shall demonstrate operation of selected fan coils in accordance with specifications including the following:

a. Cooling only fan coils:

(1) Verify fan coil unit response to room temp set point adjustment.

1. Check blower fan airflow. _____ L/scfm
2. Check cooling coil water flow. _____ L/srpm
3. Verify proper operation of cooling water control valve. _____
4. Cooling mode inlet air temperature _____ deg CF
5. Cooling mode outlet air temperature _____ deg CF
6. Calculate coil sensible capacity and compare to design:
Calculated _____ WattsBTU/hr Design _____ WattsBTU/hr

b. Cooling/heating fan coils:

(1) Verify fan coil unit response to room temp set point adjustment.

1. Check blower fan airflow. _____ L/scfm
2. Check cooling coil water flow. _____ L/srpm
3. Verify proper operation of cooling water control valve. _____
4. Check cooling mode inlet air temperature. _____ deg CF
5. Check cooling mode outlet air temperature. _____ deg CF
6. Calculate cooling coil sensible capacity and compare to design:
7. Calculated _____ WattsBTU/hr Design _____ WattsBTU/hr
8. Check heating coil water flow. _____ L/srpm
9. Verify proper operation of heating water control valve. _____
10. Check heating mode inlet air temperature. _____ deg CF
11. Check heating mode outlet air temperature. _____ deg CF
12. Calculate heating coil capacity and compare to design:
Calculated _____ WattsBTU/hr design _____ WattsBTU/hr

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____

Design Agency Representative

Contracting Officer's Representative

Using Agency's Representative

Functional Performance Test Checklist - Unit Heaters

The Contracting Officer will select unit heaters to be spot-checked during the functional performance test. The number of terminals shall not exceed 10 percent. Hot water systems {for hot water unit heaters} must be in operation and supplying design hot water supply temperature water.

1. Functional Performance Test: Contractor shall demonstrate operation of selected unit heaters:

- a. Verify unit heater response to room temperature set point adjustment. _____
- b. Check heating mode inlet air temperature. _____ deg CF
- c. Check heating mode outlet air temperature. _____ deg CF
- d. Record manufacturer's submitted fan capacity _____ L/scfm
- e. Calculate unit heater capacity using manufacturer's fan capacity and recorded temperatures and compare to design.
- f. Calculated _____ WattsBTU/hr Design _____ WattsBTU/hr

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Design Agency Representative	_____
Contracting Officer's Representative	_____
Using Agency's Representative	_____

Functional Performance Test Checklist - Steam/Hot Water Converter

For Converter: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of heating system in accordance with specifications including the following: Start building heating equipment to provide load for converter.

- a. Verify control system energizes. _____
- b. Verify converter senses hot water temperature below set point and control system modulates steam valve. _____
- c. Shut off building heating equipment to remove load on heating system. Verify converter steam valve closes after load is removed. _____

2. Verify converter inlet/outlet pressure reading, compare to converter design conditions and manufacturer's performance data.

	DESIGN	ACTUAL
Converter inlet water temp deg CF	_____	_____
Converter outlet water temp deg CF	_____	_____
Converter inlet steam pressure kpapsig	_____	_____
Determine water flow rate based on pressure drop through converter (L/SGPM)	_____	_____
Determine water flow rate with flow measuring device L/SGPM	_____	_____
Verify that temperature of water is in accordance with outdoor air reset schedule	Current Setpoint	Actual Temperature
	_____	_____

- 3. Verify proper operation of converter safeties. _____
- 4. Check and report unusual vibration, noise, etc. _____

5. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist _____

Contractor's Mechanical Representative _____

Contractor's Electrical Representative _____

Contractor's TAB Representative _____

Contractor's Controls Representative _____

Design Agency Representative _____

Contracting Officer's Representative _____

Using Agency's Representative

Functional Performance Test Checklist - Computer Room Unit

For Computer Room Unit: [_____]

1. Functional Performance Test: Contractor shall verify operation of computer room unit in accordance with specification including the following:

a. System safeties allow start if safety conditions are met. _____

b. Verify cooling and heating operation by varying thermostat set point from space set point to space set point plus 5.510 degrees, space set point minus 5.510 degrees, and returning to space set point.

c. Verify humidifier operation by varying humidistat set point from space set point to space set point plus 20 percent RH, and returning to space set point.

d. Verify that airflow is within tolerance specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS.

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist _____

Contractor's Mechanical Representative _____

Contractor's Electrical Representative _____

Contractor's TAB Representative _____

Contractor's Controls Representative _____

Design Agency Representative _____

Contracting Officer's Representative _____

Using Agency's Representative _____

Functional Performance Test Checklist - HVAC Controls

For HVAC System: [_____]

The Contracting Officer will select HVAC control systems to undergo functional performance testing. The number of systems shall not exceed 10 percent. Perform this test simultaneously with FPT for AHU or other controlled equipment.

1. Functional Performance Test: Contractor shall verify operation of HVAC controls by performing the Performance Verification Test {PVT} test for that system. Contractor to provide blank PVT test procedures previously done by the controls Contractor.

2. Verify interlock with UMCS system_____.

3. Verify all required I/O points function from the UMCS system_____.

4. Certification: We the undersigned have witnessed the Performance Verification Test and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist	_____
Contractor's Mechanical Representative	_____
Contractor's Electrical Representative	_____
Contractor's TAB Representative	_____
Contractor's Controls Representative	_____
Design Agency Representative	_____
Contractor's Officer's Representative	_____
Using Agency's Representative	_____

Functional Performance Test Checklist - Energy Recovery System

For Energy Recovery System: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of energy recovery system in accordance with specifications including the following: Start equipment to provide energy source for recovery system.

a. Verify energy source is providing recoverable energy. _____

b. Verify recovery system senses available energy and activates. _____

2. Verify recovery system inlet/outlet readings, compare to design conditions and manufacturer's performance data.

	Design	Actual
Primary loop inlet temp (degrees CF)	_____	_____
Primary loop outlet temp (degrees CF)	_____	_____
Primary loop flow rate L/s [gpm] [cfm]	_____	_____
Secondary loop inlet temp (degrees CF)	_____	_____
Secondary loop outlet temp (degrees CF)	_____	_____
Secondary loop flow rate L/s [gpm] [cfm]	_____	_____
Primary loop energy WattsBTU/hr	_____	_____
Secondary loop energy WattsBTU/hr	_____	_____

3. Verify that recovery system deactivates when recoverable energy is no longer available. _____

4. Check and report unusual vibration, noise, etc. _____

5. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date

Contractor's Commissioning Specialist _____

Contractor's Mechanical Representative _____

Contractor's Electrical Representative _____

Contractor's TAB Representative _____

Contractor's Controls Representative _____

Design Agency Representative _____

Contractor's Officer's Representative _____

Using Agency's Representative _____

- End of Appendix B -

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